THE
AGRICULTURAL NOTEBOOK

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PRIMROSE McCONNELL'S

THE AGRICULTURAL NOTEBOOK

FACTS AND FIGURES FOR FARMERS, STUDENTS AND ALL ENGAGED OR INTERESTED IN FARMING

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FOREWORD

by

SIR RICHARD HADDON, C.B.E.

Chairman of "Farmer and Stock-Breeder"
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THE fact that this is the thirteenth edition of Primrose McConnell's Agricultural Notebook is proof of the success of this book in filling the needs of farmers, students, research workers and advisers for upwards of a century. Part of the reason for this success has been the way in which the Notebook has dealt, concisely yet comprehensively and soundly, with every aspect of agriculture. And part has been the manner in which the thorough revision of each edition has kept the information in the Notebook up-to-date, and has made it the handiest all-embracing textbook of farming at all times.

The twelfth edition appeared as recently as 1953. But so rapid is the pace of agricultural progress that it has been necessary to rewrite more than nine-tenths of the matter in this, the thirteenth edition. A comparison with the previous edition will show that the sections on machinery, weed and insect pest control, grain drying and storage, farm buildings, artificial insemination, animal health, agricultural legislation, and farm accounts have been either expanded out of all recognition or are completely new.

Agricultural science and practice are also becoming so complex that it is beyond the capacity of any one man to write with equal authority on all its aspects. Professor H. I. Moore, who has edited both the twelfth and thirteenth editions, has had the collaboration of leading authorities in the preparation of the sections of this Notebook.

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SOILS

FORMATION OF SOIL

THE inorganic constituents of soils have their origin in the rocks of the earth's crust. These rocks, variously grouped under the names igneous, metamorphic and sedimentary according to their mode of formation, are exposed to weathering by physical or chemical agencies by means of which disintegration and/or decomposition are brought about.

Physical distintegration of rocks and rock minerals involves no change in chemical constitution. It is brought about by differential expansion and contraction consequent on marked temperature changes as in desert areas. In colder climatic zones it may be accomplished by the expansive action of water freezing in cracks and fissures of rocks. Plant roots may similarly extend such cracks. Moving ice, glaciers or ice sheets, produces an abrasive and grinding effect; rock so removed from the earth's surface may be taken up within the ice and transported for considerable distances undergoing further comminution in transit. When the ice retreats the deposit that remains is known as glacial till. With it are associated bedded sands and gravels consisting of material re-sorted by water following the melting of the ice. Eskers are also stratified deposits; drumlins and kames are composed of unassorted till. Rapidly moving water, for example mountain streams, may reduce the size of boulders.

Movement of distintegrated debris by water results in the formation of alluvial deposits such as flood plains or river terraces. The type of material deposited depends upon the velocity of the water by which it is borne. Thus coarse sediments are the first to be dropped and finer material is carried farther. Some weathered material may be deposited as sub-aqueous or lacustrine deposits; some eventually reaches the sea to form deltas. Wind also may possess an abrasive action and it is responsible for carrying and depositing fine-grained particles. Examples of such wind-borne deposits are coastal sand dunes and loess.

The chemical weathering of rocks proceeds simultaneously and results in their decomposition. It is accomplished by the solvent action of water which may be increased by the

presence of dissolved substances such as carbon dioxide, oxygen, organic acids and alkalis.

Rocks may be regarded as containing three main groups of chemical constituents, (*a*) strong bases such as soda (Na_2O), potash (K_2O), lime (CaO) or magnesia (MgO), (*b*) the sesquioxides or weak bases iron oxide (Fe_2O_3) or aluminium oxide (Al_2O_3) and (*c*) silica or silicon dioxide (SiO_2). Each group is affected by one or more of the processes collectively responsible for chemical weathering.

Hydration, assumption of water, increases the volume and softens the rocks so that they become more readily affected by physical and chemical weathering agencies. Hydrolysis, a double decomposition, occurs when water reacts with and removes the strong bases from combination producing hydroxides. As the water contains dissolved carbon dioxide carbonation occurs, the hydroxides being rapidly converted into carbonates. Oxidation may affect the hardness and increase the volume of some rock material. Owing to the presence of water, solution of the soluble constituents or soluble products occurs and the water which issues from rocks contains soluble salts of such elements as sodium, potassium, calcium and magnesium.

In the absence of agencies of transportation the weathered products tend to accumulate and protect the country rock from further weathering action. When such accumulations are predominantly inorganic in character they are known as residual materials. Accumulations of organic material are called cumulose. The former has usually undergone extensive weathering and, in humid regions, is well oxidised and intensely leached. In cool dry climates where weathering is less severe and chemical decomposition proceeds more slowly the intensity of leaching is less and the residual material is of higher base status.

Cumulose materials are accumulations of organic matter formed by the decay of plants in lakes, ponds and swamps. Examination of these deposits shows the successive transition from the lower hydrophytes such as sphagnum to the higher shrubs and trees. They contain, in addition, varying amounts of mineral matter such as silt and clay.

Colluvial materials have been moved from position by gravity, as in the case of rock debris or talus at the foot of slopes. Movement is accelerated by cultivation and assisted

by frost action. Typical soil material is coarse and stony because of the predominance of physical weathering.

The establishment of micro-organisms and the higher plants and the accumulation of organic residues marks the beginning of the transition from soil material to soil. Thus the formation of soil is a biochemical process.

Soils derived from the weathering of igneous rocks are called primary soils. While the same physical and chemical factors bring about the weathering of sedimentary rocks, the latter have already passed through a cycle of weathering before denudation, transportation and their deposition as sub-aqueous sediments took place. Consequently, the effect of parent material is much more marked and the clay fractions of such soils are richer in SiO_2 than those of primary origin.

SOIL PROFILE

The vertical section of soil as seen in the sides of a pit is known as the soil profile, and the individual layers of which it is composed down to the parent material as horizons.

Two sets of processes are involved in soil formation, first, physical and chemical weathering which give rise to the parent material and, secondly, profile development from the parent material. Usually the former precedes the latter but they may proceed simultaneously. Soils in which development has been allowed to proceed without disturbance exhibit distinctive profiles the characters of which are utilised for purposes of soil classification and survey.

The upper layers of soil generally contain appreciable amounts of organic matter the accumulation of which produces a darkening of colour; such layers are termed the A horizon. They make up the plough layer, furrow slice or surface soil. This horizon merges into a layer markedly weathered but comparatively free from organic matter and known as the B horizon. At its base the B horizon or subsoil is succeeded by the C horizon or parent material, the upper part of which is often considerably weathered and the base of which passes into the country rock.

CONSTITUENTS OF SOIL

The main constituents of soils are mineral matter, organic matter, water and air.

The mineral matter or more solid phase consists of rock

fragments, formed by physical and chemical weathering, in various stages of decomposition. Intimately mixed with this material is organic matter, an accumulation of vegetable and animal residues in an active state of decay. In a particular soil the amount of this material varies with the horizon. The organic matter may consist of recognisable remains of plants but much of it is present as a dark coloured amorphous substance called humus (or humified organic matter). The amount of organic matter in soils varies but in British agricultural soils is commonly about 8–10 per cent. Occurring between large solid particles and within and between clusters of small particles (aggregates) are pores of variable size which are occupied by water and air. The amount of these components is governed by the mineral and organic matter.

MINERAL MATTER

The mineral matter consists of particles of varying sizes; the relative proportion of each size present in a particular soil is determined by mechanical analysis. On the International Scale a soil is divided into gravel, the material which is retained on a 2 mm. sieve, and fine earth which passes through. The fine earth is subdivided into coarse sand, fine sand, silt and clay. The upper limit for the diameter of the coarse sand particles is taken as 2 mm., of fine sand 0·2 mm., of silt 0·02 mm. and of clay 0·002 mm. From the mechanical composition an approximate idea of the texture of a soil may be obtained.

The coarse fractions of soil, namely, sand and silt are composed of crystalline mineral particles which originated in the primary rocks of the earth's crust or of microcrystalline aggregates formed from the products of weathering or from organic residues.

The most important minerals found in these fractions are (*a*) quartz, (*b*) the felspars which are silicates of aluminium and contain varying amounts of silicates of potassium, sodium and calcium, (*c*) micas, silicates of aluminium and potassium with silicates of iron, magnesium and sodium, (*d*) pyroxenes and amphiboles, two closely related families of minerals which in chemical composition are essentially silicates of iron, magnesium and calcium and (*e*) various other minerals such as tourmaline, rutile and the iron oxides, haematite, magnetite and limonite.

Of the various minerals occurring in soils quartz is by far the commonest and it accounts for from 60 to > 90 per cent. of the sand fraction even in clay soils. The sand particles in soils formed from sedimentary rocks may contain 85–95 per cent. SiO_2, i.e., sand is impure silica. In clay particles the proportion of silica is of the order of 50 per cent. Clay is silicate containing in addition to silica about 35–40 per cent. alumina (Al_2O_3) and 4–7 per cent. of potash (K_2O) and other bases. In the sand fraction of Palaeozoic soils of Scotland and North Wales there is much undecomposed silicate with frequently not more than 60 per cent. SiO_2.

CLAY FRACTION

As the mineral particles become finer the rock minerals tend to disappear to be replaced by their decomposition products which take the form of new minerals relatively stable under soil conditions. These minerals are more reactive than the rock minerals and can take part in cation or base exchange.

Clay particles are crystalline in nature and composed of layers of hydrated alumina and silica linked by oxygen atoms.

The clay minerals present in soil fall into the following groups:

(*a*) *Kaolin Group* ($Al_2O_3.SiO_2.xH_2O$)—(i) Kaolinite; (ii) Anauxite; (iii) Halloysite.

The crystal lattice of this group of minerals consists of one sheet of silica atoms to one of alumina. They have a low base exchange capacity and little power to absorb water.

These clays are formed under conditions of low base supply in well drained areas. Where climatic conditions are appropriate and drainage less free a group of clays known as Illites, intermediate between Kaolinite and Montmorillonite clays, is formed.

(*b*) *Montmorillonite Group* ($Al_2O_3.3\text{-}5SiO_2.xH_2O$)—(i) Montmorillonite; (ii) Pyrophyllite; (iii) Beidellite; (iv) Nontronite.

The physical and chemical properties of this group of minerals are quite distinct from those of the Kaolin group. They possess units of two layers of silica to one of alumina, and their expanding lattices permit of a high degree of hydration and cation adsorption.

Montmorillonite clays are formed in areas of poor drainage which ensures a satisfactory supply of bases.

In addition to these secondary minerals clay also contains in varying amounts free oxides of iron and titanium, and alumina, silica and micas.

ORGANIC MATTER

Soil is differentiated from rock debris by the presence of organic matter which originates in complex organic compounds synthesised by plants from carbon dioxide.

Under virgin conditions increments of organic matter take the form of plant and animal remains; in agricultural practice it is increased by above-ground crop residues, crop roots and applied plant and animal materials.

COMPOSITION OF ORGANIC MATTER

Fresh organic matter, i.e. crops grown for green manuring, consists of about 75 per cent. moisture and 25 per cent. dry matter. The dry matter is made up of 11 per cent. carbon, 10 per cent. oxygen, 2 per cent. hydrogen and 2 per cent. ash.

In addition small amounts of nitrogen, sulphur, phosphorus and other elements are present.

The composition of plant materials varies greatly with species and within a species. Leguminous crops have higher nitrogen contents than straw and roots which are rich in carbonaceous matter.

The amount of organic matter present varies with the type of soil and the system of management. Thus uncultivated upland soils may contain as little as 2 per cent. while peats may contain 90–95 per cent. of organic matter.

In general there is a gradual decrease in the amount of organic matter in the soil from the surface downwards.

SOIL MICRO-ORGANISMS

The decomposition of organic matter may take place by purely chemical means but usually the process is assisted by the activities of micro-organisms. These micro-organisms include the *Micro-fauna*, examples of which are protozoa, nematodes, worms and insects, and the *Micro-flora*, such as algae and diatoms, fungi, actinomycetes and bacteria.

Soil bacteria, the numbers of which have been variously estimated at from 2–200 millions per gram of soil, are numeri-

cally superior to the other groups of micro-organisms. They may be classified into *Heterotrophic organisms* of which the nitrogen-fixing bacteria (free-living or symbiotic), the ammonifying bacteria and the cellulose-splitting bacteria are examples, and *Autotrophic organisms* represented by the nitrifying bacteria, the sulphur bacteria and the iron bacteria.

The former group derive energy and carbon for growth from the oxidation of complex organic compounds. They include organisms which utilise atmospheric oxygen to build up body protein. Autotrophic bacteria obtain energy from the oxidation of inorganic compounds and carbon from carbon dioxide. In this group are organisms with specific functions, e.g., nitrosomonas which oxidises ammonia to nitrite and nitrobacter which oxidises nitrite to nitrate.

DECOMPOSITION OF ORGANIC MATTER

In addition to fresh green materials, soil organic matter consists of faecal and plant residues.

The rate of decomposition varies with the age and maturity of the organic material. Plant residues, of which the chief constituents are structural carbohydrates with small amounts of proteins, waxes, and other compounds, are decomposed with difficulty compared with fresh material.

Carbon dioxide and water are the end products of the simplification of carbohydrates while amino-acids and ammonia result from the breakdown of nitrogenous constituents. Not all the carbohydrate and protein are completely oxidised but reach a stage at which a complex colloidal material known as humus is produced.

The decomposition of organic matter is essentially an oxidative process. Soils which absorb the greatest amount of oxygen and produce the greatest amount of carbon dioxide in a given time are, it has been suggested, of higher fertility than those in which oxygen absorption is less, but while this may be true in similar soils under similar conditions generalisation is impossible.

CARBON : NITROGEN RATIO OF SOIL ORGANIC MATTER

The ratio of carbon to nitrogen in materials such as cereal straws, added to the soil as unharvested residues, is of the order of 40 : 1. Leguminous residues have narrower ratios because of their higher nitrogen content. The C : N ratio

of cultivated soils of temperate regions is 10 or 12 : 1 and, since the amount of unaltered plant residues in the soil is small, the ratio approximately represents that of the soil humus.

When additions of organic matter with C : N ratios greater than that for the soil are made carbon dioxide is evolved due to increasing activity on the part of micro-organisms. The latter require supplies of nitrogenous compounds for elaboration into body protoplasm and these supplies are taken from the soil. Consequently a temporary reduction in the amount of ammoniacal and nitrate nitrogen present in the soil occurs.

COMPOSITION AND PROPERTIES OF HUMUS

Humus contains approximately 50 per cent. of carbon, 35 per cent. of oxygen and 5 per cent. of each of nitrogen, hydrogen and mineral matter. It differs little in composition from whatever source it be obtained.

In the formation of humus, lignin is probably the most prominent plant constituent. It is associated with protein as a ligno-proteinate, i.e., a lignin-protein complex relatively stable in the soil and known as the humus-nucleus.

While not a distinct chemical compound of fixed composition humus possesses definite chemical properties. It exhibits acidic and base-exchange properties; it can thus form salts (which are electrolytes) and take part in cation exchange reactions.

Because of its colloidal nature and high internal surface it possesses in a marked degree the power to adsorb gases. In addition, when it absorbs water, the absorption is accompanied by a marked increase in volume; when it dries out shrinkage occurs.

EFFECTS OF ORGANIC MATTER ON THE SOIL

Undecomposed organic matter has a beneficial opening effect on heavy soils; on light soils the effect of applications of unhumified material is to increase their open texture with detrimental results. Hence the respective values of " long " and " short " farm manure to heavy and light soils.

Humus is associated with colloidal clay in the development of that condition of granulation or aggregation of soil particles known as a " crumb structure."

Because of its colloidal nature humus can hold coarse particles together and, with its capacity to absorb water, it gives body to light soils and increases their water holding capacity. In the absence of calcium humus may aggravate the water relationships of heavy soils; with calcium humus assists in aggregate or crumb formation in such soils and thereby improves drainage.

By its intimate distribution in soils, especially as a coating over the particles, humus confers a dark colour on the soil. This has the effect of raising its spring temperature with subsequent beneficial effects on crop germination and growth.

In addition organic matter acts as a source of energy for soil organisms and its decomposition products provide nitrogen, phosphorus, potassium, sulphur and other simple substances for plant nutrition.

PROPERTIES OF COLLOIDAL CLAY

Some idea of the infinitesimal size of colloidal particles and the immense surface they expose is given by the fact that a cubic foot (80 lb.) of colloidal particles has been estimated to have a total surface area of about 150 acres.

Clay and humus are examples of colloidal electrolytes. They possess one polyvalent ion of colloidal dimensions with a corresponding number of simple ions of opposite sign. In their reactions clay and humus particles behave as polyvalent anions with a large number of cations attached.

Colloidal clay occurs in intimate association with soil organic matter, has marked water absorptive capacity and thus confers on soils a high water-holding capacity. The release or assumption of water is accompanied by changes in volume; thus a clay soil shrinks on drying. Plasticity and cohesion, are further properties controlled by the colloidal phase. It is sensitive to small quantities of electrolytes.

FLOCCULATION OF SOIL PARTICLES

In general neutral salts of such bases as sodium, potassium and ammonium produce flocculation of particles in suspensions of calcium-free silt or clay; the hydroxides will not. A similar result is obtained with calcium hydroxide and neutral calcium salts in silt suspensions but in clay suspensions flocculation is brought about better by the hydroxide.

Under the conditions of alkalinity obtaining in the presence of calcium hydroxide the gelatinous and siliceous surface of colloidal clay forms a coagulum with calcium which more than balances the deflocculating effect of the hydroxide on the particles.

IONIC EXCHANGE

Colloidal particles are regarded as possessing an inner shell of negative charges (anions) and an outer diffuse layer of positive charges (cations) which, although tethered to the particles, are free under certain conditions to exchange places with other cations.

Owing to the presence of water in and around the colloidal particles some of the materials present may be either in solution or in a mobile, reactive state. The cations are capable of being instantaneously exchanged by others, the order of replacement being H>Ca>Mg>K>Na.

In other words hydrogen ions (H^+) and calcium ions (Ca^{2+}) are the most active. The exchange takes place on a basis of chemical equivalents and is practically unaffected by temperature. Cationic (base) exchange reactions are usually reversible and the adsorbed cations greatly affect the physical properties of soils. These factors are of great importance in soil management.

There is an upper limit to the capacity of a soil for exchangeable bases at which point the soil is said to be base-saturated, i.e., the base exchange capacity of the soil has been satisfied. Under agricultural conditions this most frequently happens when a soil has long been in equilibrium with calcium carbonate. In the absence of calcium carbonate the amount of exchangeable bases held by a given weight of soil may fall below the saturation point and the soil is described as base-unsaturated. Such a condition can arise when a soil has been leached by the percolation of water containing dissolved carbon dioxide.

In Great Britain the exchangeable cations occur in similar proportions to those reported by Hissink from Holland, namely, 79 per cent. Ca, 13 per cent. Mg, 2 per cent. K and 6 per cent. Na.

When hydrogen ions displace calcium ions the colloidal particles tend to become acid by reason of the hydrogen gained. Thus acid soils, i.e., soils which have been leached,

have their base exchange capacity largely satisfied by hydrogen. The colloidal complex of soils which have been inundated with sea water for a short time becomes saturated with sodium ions with the result that the soil becomes sticky. Reclamation consists in replacing the sodium with a neutral calcium salt such as gypsum.

PHYSICAL PROPERTIES OF SOILS

Factors which influence the physical properties of soils include the type and size distribution of the non-colloidal particles, the character and content of the colloidal matter, their structure and their moisture content. The character of the colloidal matter is closely related to the respective amounts of inorganic and organic colloids and to the content of adsorbed bases.

SOIL TEXTURE

The textural classification of a soil, following mechanical analysis, may be obtained by the use of triangular co-ordinates, a method devised by the United States Department of Agriculture.

To assess texture in the field a small amount of wet soil may be rubbed between fingers and thumb and a rough division into coarse and fine sand, silt and clay made. Experienced workers can distinguish ten or more texture classes by this means.

In the cases of sands and clays the dominant mineral fraction gives its name to the soil texture group but in the case of loams predominance cannot be assigned to any one particle size since all are represented.

INTERNAL SURFACE OF SOILS

The total surface of all particles per unit weight of soil is its internal surface. On the assumption that all particles are spherical the internal surface may be calculated from the mechanical analysis using the average diameter of the particles in each size group.

TRUE AND APPARENT DENSITY

The true density (T) is an additive function of the individual densities of the soil constituents to which each contributes its proportionate share. The apparent density (A) is the

density of the soil as a whole, i.e., of particles and pore space.

The densities of the principal soil constituents, with the exceptions of, for example, magnetite (4·9 – 5·2) and organic matter (1·2 – 1·7), fall within the narrow range (2·5 – 2·8). The true density therefore largely depends on the relative proportions of organic and inorganic matter present.

The weight per unit volume of dry soil is the apparent density and in this determination air or pore space is included in the volume. Hence the apparent density is represented by a lower figure than that for true density.

PORE SPACE

The relationship between the true and apparent densities and the pore space (P) may be represented thus:—

$$P = \frac{T - A}{T}$$

and expressed as a percentage.

The pore space in soils rarely exceeds 50 per cent. as in sands or falls below 30 per cent. as in clays. It depends upon the size, shape and degree of compaction of the soil particles and their state of aggregation, for example, into crumbs or other structural units. It may be increased by additions of organic matter.

Although clays possess a greater total porosity than sands the pore spaces in the latter, due to their greater volume, are more conducive to good drainage and aeration. Thus the advantage of aggregation of soil particles is that the increase in proportion of macro-pore space to micro-pore space leads to better drainage and aeration.

Pore space may be increased by harrowing and decreased by rolling, trampling by stock or any treatment which results in the destruction of aggregates, such as the use of deflocculating agents.

The soil is a three-phase system—consisting of solids, i.e., mineral and organic matter, with liquids and gases as dependent variables occupying the pore spaces. Little variation takes place in the solid phase but the proportion of solids to liquids and gases is constantly changing. Thus as water is lost by transpiration, evaporation and drainage the proportion of gas increases while air may be displaced by increments of water in the form of heavy rain.

PLASTICITY

The property of plasticity, which is largely due to the mineral colloidal material present, is the ability of a moist soil to change its shape in response to an applied force. With the presence of increasing amounts of water the soil becomes more and more plastic until the upper limit is reached after which a thin suspension is produced. At the lower limit of plasticity a soil will break down and crumble due to its inability to change shape under the influence of applied stress.

Plastic soils are cohesive, hence soils which are capable of being moulded set into hard clods on drying.

SOIL STRUCTURE

Structure is the consequence of the aggregation of primary soil particles into compound particles or aggregates although certain forms are of the single-grain type. For plant growth the crumb or granular structures are required.

Soil structure is affected by growing plants through their residues as organic matter, by their root activity and by the protection they provide against impact of rain. Adsorbed cations also affect structure, calcium having the ability to flocculate the soil colloids whereas sodium is a deflocculant. The activities of fungi, the mycelial threads of which have a temporary binding effect on soil particles, and bacteria, which secrete mucous that also exerts a temporary or permanent binding effect depending on the type of gum secreted, are other factors affecting structure development.

SOIL TEMPERATURE

The mean soil temperature closely approximates the mean air temperature throughout the year although there may be wide seasonal and diurnal fluctuations according to the distance below the surface.

The specific heat of soil is of importance for on it depends the response of a given soil to additions or losses of heat by radiation and of losses by vaporisation from wet soils.

The specific heat of a soil depends upon the proportions of sand, clay and humus present and varies even more greatly with the moisture content. Thus the volume specific heat (in Cal./c.c.) of dry sand is 0·3 and that of wet sand 0·7 (Sp.

Ht. of water = 1). Since even more water is required to saturate clay and humus the specific heats of wet soils of these types will be higher than that of a saturated sand.

In consequence moist soils respond more slowly to solar radiation, the only important direct source of heat to the soil, than dry soils and on them plant growth commences later in the spring.

Most crops are capable of germination and growth at fairly low temperatures and farming practice has, in fact, long taken into account the temperature requirements of seeds and crops with the result that frost sensitive crops are not planted in cold soils.

FACTORS AFFECTING SOIL TEMPERATURE

The diurnal and seasonal variations in soil temperature become less marked with increase in depth in the soil. Minor variations are caused by clouds which reduce radiation losses from the soil and by winds which, inducing an increased rate of evaporation of moisture, produce a cooling effect.

Site, slope and aspect are further factors which influence soil temperature, e.g., air temperature decreases by 1° F. for every 300 ft. increase in altitude; in the northern hemisphere southerly slopes are warmer than northerly slopes since they receive more direct insolation.

Dark colours absorb heat better than light colours and dark coloured or red soils similarly absorb more heat in sunshine than do light-coloured soils. The effect on plants is to increase the rates of germination and growth.

Thermal conductivity is increased by compaction and by the presence of water, which is a relatively good conductor, in the fine pores. Because of the insulating effect of air in the pore spaces, loose dry soils conduct heat slowly. The water content of the soil also influences soil temperature. Thus the high specific heat of wet soils which necessitates a greater quantity of heat to bring about marked changes in soil temperature, may be considerably reduced by the removal of excess water by drainage. The effect of drainage is to lower the specific heat of wet soils and reduce the heat lost in the process of evaporation.

SOIL AIR

The soil air is closely associated with the solid phase in the form of mineral and organic matter and the liquid phase

n the form of the soil solution. There is, in the soil, an equilibrium between these three phases and changes in any one phase are accompanied by changes in the other two phases. It is clear therefore that both the volume and the composition of the soil air will be directly influenced by the soil solution and indirectly by the solid phase (in particular by the colloidal matter) due to its effect on the soil solution. Thus there is a constantly shifting equilibrium between these three phases.

Soil air differs from the atmosphere in containing a much higher proportion of carbon dioxide, 0·2 per cent. compared with 0·03 per cent. and having a relative humidity of the order of 100 per cent. (i.e., it is saturated with water vapour). It contains less oxygen, 20·6 per cent. compared with 20·99 per cent; some is adsorbed by the colloidal surface and an appreciable proportion is dissolved in the soil water.

The amount of carbon dioxide present varies with the rate of microbiological decomposition; it is highest in spring and autumn when the soil may be warm and moist and lowest in summer and winter when moisture and temperature conditions may be unfavourable for the activities of micro-organisms.

Because of the high relative humidity conditions are favourable for the growth of fungi, bacteria and other micro-organisms whose activities are chiefly controlled by temperature. The carbon dioxide content rises to a maximum in spring, falls in summer and rises again in autumn although not to the level reached in spring. The rate at which it is produced depends to some extent upon the aeration of the soil, the oxidative decomposition of organic matter being an aerobic process.

The concentration of carbon dioxide in the soil air at any time depends on the rate at which it is produced by microbiological activity and the rate of diffusion from the pore space to the atmosphere.

It is temporarily increased by additions of organic matter, by rainfall and root respiration and is temporarily reduced by ploughing, which increases the rate of diffusion, and sudden changes in temperature.

Apart from the air which is free to diffuse, the soil also contains air held by the colloidal matter or dissolved in the soil solution. The composition of the adsorbed air is approxi-

mately 90 per cent. carbon dioxide and 10 per cent. nitrogen with a trace of oxygen.

SOILS AND WATER SUPPLY

Rain water reaching the soil passes into the subsoil when the absorptive capacity of the surface soil has been satisfied. The former is removed by drainage and the latter by evaporation or transpiration by plants.

The amount of water draining from the soil is greater in winter when there is little plant growth and evaporation is low than in summer when these factors have maximum effect. The mean annual loss by percolation is roughly 50 per cent. of rainfall. Under cropped soils loss of water by percolation is of the order of 25–30 per cent.

DRAINAGE WATER

The chief constituents of drainage waters in cool temperate climates are calcium and sodium, the latter being almost completely removed from the soil. The anions most easily removed are nitrate, sulphate, chloride and bicarbonate. According to E. J. Russell, "Soil Conditions and Plant Growth," the concentration of the drainage water varies from 200–500 p.p.m. equivalent to 0·02–0·05 per cent.

SOIL WATER

Three forms of soil water are recognised: HYGROSCOPIC WATER which is adsorbed by a completely dry soil from an atmosphere of water vapour as a result of attractive forces in the surfaces of particles; CAPILLARY WATER which is held by surface tension as a continuous film around the particles and in the capillary spaces and GRAVITATIONAL WATER.

SOIL MOISTURE CONSTANTS

The following terms are in common usage:—

Maximum Water Capacity—The amount of water that a soil can hold when completely waterlogged, i.e., when all available pore space is occupied by water.

Field or Moisture Holding Capacity—The water held in a soil after excess water has drained away under the influence of the force of gravity.

This map is the figure 9 referred to on page 41, and not the map on page 47.

FREQUENCY OF IRRIGATION NEED
(Years in ten)

P.T.O.

ERRATA

Page 55: First line of Table 4 should read:-

Diameter in inches	Cross sectional area in square feet	Maximum area acres
9	0·44	30

Page 59: First line of Table 5 should read:-

Distance between drains yds.	Feet per acre	Chains per acre
5	2,904	44

Fourth line should read:-

14	1,037	15·7

Page 79: Paragraph on Basic Slag, line 10—reference to citric acid should read "2 per cent. citric acid solution".

Hygroscopic Coefficient—The percentage of water which a completely dry soil adsorbs from an atmosphere of known relative humidity. It probably varies between about 3 per cent. in light textured soils and 13 per cent. in soils of heavy texture.

Wilting Coefficient (percentage) is the point at which the soil ceases to be able to supply the plant with water at a sufficient rate to maintain turgidity and hence the plant permanently wilts.

Moisture Equivalent—The amount of water held by a soil against a force which tends to remove it. The force ($1{,}000 \times g$) is usually applied by centrifuging.

Probable Relationships of Soil Water Constants—
Hygroscopic coefficient = $0{\cdot}68 \times$ Wilting Coefficient.
Moisture equivalent = $1{\cdot}84 \times$ Wilting Coefficient.

MOVEMENT OF WATER IN SOILS

Hygroscopic Water—The lower the water content of a soil the more strongly is that water held and, consequently, the greater will be the suction pressure required to remove it. This water, which can be regarded largely as in a non-liquid condition, is adsorbed at the surface of soil and organic matter particles as a thin film not more than 4–5/1,000,000 mm. (4–5 mu) thick. It is held by a pressure equivalent to c. 20,000 atmospheres or roughly 300,000 lb./sq. in. and its adjustment is confined to evaporation and condensation.

Capillary Water is that water which is held against the pull of gravity and is present as thin films around the soil particles and in the capillary spaces. The force holding the water in position is due to molecular attraction and movement is as a liquid from thick films to thinner films.

Capillary water is the only permanent form in which soil moisture exists in the liquid state. It contains substances in solution and may therefore be regarded as the soil solution.

Gravitational Water is of a transitory nature in the soil, draining under the influence of gravity.

CAPILLARY POTENTIAL

Capillary potential is the work required to withdraw a unit mass of water from a unit mass of soil. The force

exerted (which is in fact a suction pressure) in this withdrawal is less in the case of a soil saturated with water than in one which is just moist. The force, expressed in terms of the height of a column of water in centimetres corresponding to this suction pressure, is known as the capillary potential.

pF

To avoid the use of the unwieldly figures necessary to express the force required to remove moisture from the soil the logarithm to the base 10 of the capillary potential is used. This value is usually termed pF.

MOISTURE PERCENTAGE AND pF

	pF
Moisture Equivalent	2·7
Field Capacity	3·0–3·2
Wilting Coefficient	4·2
Hygroscopic Coefficient	4·5

SOIL SOLUTION

The movement of water in the soil brings into solution most of the elements present. For all practical purposes the capillary water can be regarded as the soil solution.

Changes in the amount of the solution are dependent on the rainfall, the absorptive and retentive capacity of the soil, evaporation and the amount utilised by plants.

The concentration changes with variations in the rate of solution which is influenced by additions of lime, farm manure and fertilisers, by the loss of nutrients to plants and also by leaching (drainage) losses.

PLANT NUTRITION, COMPOSITION OF THE SOIL SOLUTION

The soil solution contains all the nitrate (50–300 p.p.m.) available for the plant, the concentration of nitrate decreasing with increments of water. It contains small amounts of potassium (10–40 p.p.m.) and phosphorus (1–2 p.p.m.).

Although the concentrations of potassium and phosphorus are low they are probably adequate because of the rapidity with which the soil solution is replenished by these nutrients from the soil particle. Fertile soils tend to have more concentrated soil solutions but there is no strict correlation between fertility and concentration.

SOIL REACTION AND LIME STATUS

Soils capable of improvement by liming may be infertile by reason of acidity as shown by lime requirement or pH measurements and corrected by the addition of an alkali, or by calcium deficiency which has a detrimental effect on soil structure and may lead to nutritional imbalance.

The condition of infertility known as "sourness" is characterised by the presence on arable land of certain weeds such as spurrey and mayweed, or in grassland of weeds such as sorrel and bent and old matted turf.

Certain diseases such as "finger and toe" or "club root" in cruciferous crops and the regular failure of certain crops are usually pointers to soil sourness.

Plants show varying degrees of tolerance to soil acidity, thus, sugar beet, barley, wheat and mangolds are sensitive, peas, beans, swedes and turnips are of intermediate tolerance and oats, rye and potatoes can tolerate acid soil conditions.

NATURE OF SOIL ACIDITY

Soil acidity represents the excess of hydrogen ions (H^+) over hydroxyl ions (OH') in the soil solution. At the same time there may be a reserve of acidity in the form of hydrogen ions held by the colloidal complex. The magnitude of the latter is considerable compared with that of the former although both types of acidity tend towards an equilibrium. Soil acidity is expressed in pH units by which pH 7 represents a condition of neutrality.

The pH value is the logarithm of the reciprocal of the hydrogen ion concentration; the "p" indicates that the value is logarithmic and the "H" that the hydrogen ion is under consideration. In practice the negative sign is omitted.

The correction of sourness involves the neutralisation of the acidity of the soil solution and an increase in the percentage base saturation of the colloidal complex.

Crop failures under conditions of acidity have also been ascribed to soluble aluminium compounds with some certainty in the case of barley but with reserve so far as other crops are concerned.

Calcium deficiency is an important factor in the causation of plant diseases and failures, since certain plants in the presence of sufficient calcium will tolerate low pH.

While calcium appears to be an essential plant food it is used in relatively small amounts by crops which remove only between 10 and 30 lb. of lime (CaO) per acre.

The optimum pH for all crops is between 6·5 and 7·0 and is probably close to 6·5, hence, in liming soil, no attempt should be made to produce alkaline conditions. For particular crops the critical pH, i.e., the pH at which failure is likely to occur, depends upon seasonal and other conditions.

LIME REQUIREMENTS OF SOILS

TABLE 1

APPROXIMATE WEIGHT OF LIME TO BRING SOIL REACTION TO pH 6·5
(CaO required cwt./acre)

pH	Light Loam	Medium Loam	Clay
4·0	95	100	115
4·5	70	80	95
5·0	50	60	75
5·5	30	40	55
6·0	15	20	35
6·5	0	0	15

For sands and silts, slightly smaller and slightly larger dressings respectively of lime are required. Lime requirements of soils may also be estimated from the percentage of exchangeable calcium.

Calcium (lime) may be lost from soil in the crop or by leaching; losses by leaching are greater when soils have recently been limed.

The approximate annual magnitude of these is equivalent to 3 cwt. per acre of lime expressed as CaO.

Loss of lime from the soil may be increased by the prolonged used of fertilisers such as ammonium sulphate, of protein manures such as dried blood or hoof and horn meal and by leguminous green-manure crops. This loss of lime is marked by an increase in soil acidity. Superphosphate, potassium salts, farmyard manure and non-leguminous green-manure crops do not produce any marked effect on

TABLE 2

EXCHANGEABLE CALCIUM AND LIME REQUIREMENT
(CaO required in cwt./acre)

Ex. CaO per cent.	Loam	Clay
0·00	60	70
0·05	50	60
0·10	40	50
0·15	30	40
0·20	20	30
0·25	10	20
0·30	—	10

the lime status of soils and leave the soil reaction virtually unchanged. Certain other fertilisers such as sodium nitrate, basic slag and calcium cyanamide, on the other hand, tend to reduce the acidity of soils.

NITROGEN

Nitrogen occurs in the soil in inorganic form as ammonia and nitrates and in organic combination in the form of proteins, amino-acids and other complex compounds.

The total nitrogen present in soil varies between about 0·05 per cent. in sands to nearly 1 per cent. in highly organic soils. The amount of nitrate nitrogen is very much smaller.

The sources of soil nitrogen are atmospheric nitrogen which is fixed by micro-organisms, e.g., legume bacteria and free-living bacteria, organic matter from unharvested crop residues, organic (nitrogenous) manures and inorganic nitrogenous fertilisers.

THE NITROGEN CYCLE

Plants obtain their nitrogen from such simple compounds as amino-acids and amides, and chiefly from ammonium salts and nitrates. Fresh proteins undergo rapid decomposition in the soil in contrast to the protein of soil organic matter which appears to be highly resistant to micro-biological activity.

The production of nitrates from decaying organic matter is a process of simplification whereby nitrogenous organic

matter is converted into amino-acids and amides by enzymic changes. These compounds undergo ammonification which is brought about by bacteria, fungi or by purely chemical means. Thereafter the rate of nitrification depends on the rate of ammonification. Nitrification, an oxidative process, is the work of specific organisms thus:—

$$\text{(1) Ammonium salts} \xrightarrow{\text{Nitrosomonas}} \text{nitrites.}$$

$$\text{(2) Nitrites} \xrightarrow{\text{Nitrobacter}} \text{nitrates.}$$

As the latter change is more rapid than the former nitrites rarely occur in the free state in soils.

The nitrate content of the soil fluctuates widely over short periods and the production of nitrate depends largely on seasonal influences of which the most important is temperature. It proceeds most rapidly in neutral or very slightly acid soils and in the presence of moisture. Minimum, optimum and maximum temperatures for nitrification are 5° C., 25–30° C. and 55° C. The amount of nitrate nitrogen in the soil depends upon plant requirements, the magnitude of leaching of soluble salts, the activity of de-nitrifying organisms and the ratio of carbon/nitrogen in soil organic matter.

UTILISATION OF NITROGEN BY PLANTS

Nitrogen is chiefly absorbed in the nitrate form although some crops such as potatoes utilise ammonium salts. Some plants obtain nitrogen by symbiotic relationships with certain fungi (Hymenomycetes), the roots of such plants forming, with the mycelial growth of the fungi, associations known as mycorrhizae.

NITROGEN FIXATION

Soil nitrogen may be increased by the presence of ammonia and nitric acid in rainfall which account for an increment of about 4 lb. of nitrogen per acre per annum in Great Britain. Free-living bacteria such as Clostridium pastorianum, an anaerobic organism, which functions over a wide range of pH, and Azotobacter chroococcum, an aerobic organism which appears to be inactive when the soil reaction is more acid than pH 6, are able to utilise soluble carbohydrates and

fix elementary nitrogen in the absence of inorganic nitrogen sources.

Atmospheric nitrogen may also be brought into organic combination by certain aerobic organisms, Rhizobium spp., which live in symbiosis with particular species of Leguminosae and possibly other plants. These are the nodule bacteria. In such symbiotic relationships as this the micro-organisms receive their energy supplies from the plant which in turn obtains its nitrogen by autolysis.

LOSS OF NITROGEN FROM THE SOIL

Nitrogen, as nitrate, is lost from the soil mainly by leaching. Consequently, factors which improve plant growth and thus involve a greater utilisation of water decrease losses of nitrate nitrogen. Such factors also tend to decrease the nitrogen level in the soil by reason of the increased uptake by the crop.

Nitrogen is also lost from the soil by the harvesting and removal of crops.

Under conditions of imperfect drainage and aeration and in the presence of fresh organic matter gaseous nitrogen may be lost from the soil. The loss involves the reduction of nitrate and nitrite by micro-organisms. Ammonium compounds may also be broken down and elementary nitrogen produced.

EFFECT OF NITROGEN IN PLANTS

Nitrogen is concerned with the vegetative development of the plant and to some extent it controls the efficiency of utilisation of phosphorus and potassium. A deficiency results in stunted growth and restricted root development. Visual symptoms of deficiency are yellow or yellowish green foliage; in extreme cases leaves are shed. Excess of nitrogen is manifest by dark green leaves and soft succulent growth.

By prolonging growth nitrogen, in excess, tends to delay the maturation of crops. In cereals it may cause weakness of the straw by excessive lengthening of the internodes. This generally results in "lodging." Quality may also be impaired and the factor of resistance to disease lowered.

PHOSPHORUS

Phosphorus occurs in soils as apatite—a primary mineral, as calcium, iron and aluminium phosphates—which are

secondary sources, and in organic compounds such as lecithin.

The amount present is small, generally within the range 0·02–0·04 per cent., and it is in a more or less insoluble state. Under increasingly alkaline conditions, in the presence of lime, calcium phosphates of decreasing solubility are formed.

Under intermediate conditions of acidity, e.g., pH 4·5–5, the availability of the phosphate is reduced owing to the activity of soluble iron, aluminium and manganese compounds. At about pH 7 the absorption of phosphorus by plants is repressed by the active soil calcium and, in general, solubility of phosphate appears to be greatest at about pH 5·5–6·5.

In the presence of calcium compounds, soluble mono-calcium phosphates, as in superphosphate, are rapidly converted to the di-calcium salt. This change, which is known as "reversion," takes place shortly after the superphosphate reaches the soil. As a result the phosphate is precipitated in a finely divided state; it is soluble in dilute acid and can be readily utilised by the plant. Should the process of reversion proceed further insoluble tri-calcium or even octa-phosphate may be formed.

Phosphorus affects the vigour and quality of plants rather than the yield. By hastening the maturity of crops this element is particularly valuable in short growing seasons. It encourages the development of fibrous roots and thus autumn sown crops are able to make vigorous growth in early spring. Phosphorus also counterbalances the unfavourable effects of excess nitrogen and tends to reduce lodging of cereal crops.

Visual symptoms of phosphorus deficiency are grey, purple or bronze colorations of the foliage.

POTASSIUM

Potassium occurs in the soil in the form of original minerals such as felspars and mica, as complex mineral silicates of secondary origin, and in association with the colloidal complex. The amount present in soils lies between about 0·1 per cent. in sandy soils and 3 to 4 per cent. in clays.

Together with adequate supplies of nitrogen and phosphorus, potassium is essential for the growth and vigour of crops and is concerned rather with quality than yield. It improves the natural resistance of plants to disease and insect attack. Potassium is required for chlorophyll formation and

is essential for starch formation and the translocation of sugars.

Visual symptoms of potassium deficiency are dry, scorched and curled leaf edges and intravenal chlorosis.

OTHER ESSENTIAL ELEMENTS

In addition to calcium, nitrogen, phosphorus and potassium certain other elements are required by plants.

Sulphur is present in soils in association with the proteins of organic matter and in inorganic compounds such as pyrites and gypsum. Amounts varying between 6 and 60 lb. per acre have been reported to reach the soil in rain water. The changes by which sulphur compounds become available to plants are largely biological.

Hydrogen sulphide and elementary sulphur formed during the decomposition of organic matter are oxidised to sulphites and sulphates, bacteria being largely responsible for the change. It is in the form of sulphates that plants acquire their supplies of sulphur.

Sodium, which can partially replace potassium as a nutrient for certain plants, e.g., sugar beet and mangolds, is present in all plants. Sodium salts may, in the absence of potassium, be used effectively as fertilisers (sodium nitrate being more effective than calcium nitrate or ammonium sulphate), although their effects appear to be independent of the potassium status of the soil.

Magnesium is essential for the formation of chlorophyll of which it is a constituent, and also for the formation of oil. Deficiencies of magnesium are manifest by brown patches on the leaves of apple trees, red and purple colours on the leaves of certain bush fruits and premature defoliation.

Iron is also essential for the formation of chlorophyll but is not a constituent of the chlorophyll molecule. Its absence or unavailability leads to chlorosis, i.e., yellowing of the leaves, due to the imperfect development of chlorophyll.

This condition, which can be remedied by the application of soluble iron salts, is caused by the precipitation of iron as phosphate within the plant and by excessive calcium carbonate in the soil.

Boron is associated with the calcium nutrition of plants and with the effective symbiotic relationships of Rhizobium spp.

in leguminous plants. Its absence results in " brown heart " in swedes or " heart rot " in sugar beet, which may be corrected by the application to the soil of about 20 lb./acre of borax.

Manganese is an essential constituent of plants although required in small amount. A deficiency results in leaf chlorosis and its absence results in cessation of growth. " Grey speck " disease of oats, which is due to manganese deficiency, is associated with certain soil conditions, namely, high organic matter content and high calcium status. It may be corrected by the application of about 45 lb. of manganese sulphate per acre.

Copper and Zinc in small amounts are also required for plant growth but may be toxic in high concentration. " Reclamation disease " in Holland is due to the absence of copper salts. Deficiencies of copper and hence response to soluble copper salts appear to be associated with soils rich in organic matter.

Silicon is present in all plants and appears either to increase the amount of phosphorus available in the soil or may facilitate the uptake of phosphorus by the plant.

Molybdenum is widely distributed in soils, in plants and in animals. While deficiencies have been reported in legumes and broccoli certain calcareous clays derived from the Lower Lias formation have a high molybdenum content and carry herbage with amounts of molybdenum that are detrimental to cattle and sheep and cause a condition known as " teart."

Cobalt is present in small amounts in soil and herbage. Deficiency of cobalt, which causes " pining " in sheep, may be corrected by the application of 2 lb./acre of cobalt sulphate or chloride to the soil.

SOIL ANALYSIS

Soil analysis generally involves the laboratory examination of soil to supplement the field examination. It enables certain " field " characteristics of soil to be more precisely defined and provides data on their chemical composition. Its purpose is twofold, firstly, to obtain data by which soils may be classified and their origin and constitution compared and, secondly, to assess the plant nutrient status in order that

deficiencies may be remedied by appropriate manurial treatment.

Methods used in the analysis of soil are of two types, "absolute" and "conventional." By the former, the total amount of a particular constituent or the amount falling into a definite category is determined. In the latter, the methods are of little real significance for purposes other than that of making recommendations regarding manurial policy and their use is restricted to advisory work. Because of our incomplete knowledge of the constitution of the soil and of the chemical and microbiological changes occurring therein these methods have been evolved for specific purposes, namely, to ascertain whether soils are in need of calcium, phosphorus or potassium.

The estimation of the amount of calcium (lime) required may be attempted in the field by the use of indicators to ascertain pH; in the laboratory electrometric pH determinations, the determination of exchangeable calcium or the Hutchinson and McClennan Lime Requirement method would be employed.

The wide choice of procedure suggests that the lime requirement of a soil is not an absolute figure but a matter of personal opinion. In connection with these so-called lime requirement determinations the need for correlating analytical data with crop response, seasonal data and, of even greater importance, economic conditions, is self-evident.

The estimation of phosphorus, potassium and other plant nutrients is based on a presumed distinction between total and available supplies. Various solvents, including 1 per cent. citric acid, 0·5N acetic acid, 0·5N acetic acid buffered with sodium acetate to pH 4·5, 0·2N nitric acid, 0·005N sulphuric acid and many others, have been proposed for the extraction of the "available" nutrients.

This practice is not entirely justifiable since even the most insoluble compound may make some contribution to the nutrition of plants, and each form in which a nutrient is present in the soil will be, to some extent, soluble in a given extractant.

In addition, the amount of available nutrient extracted depends upon the ratio of soil to solvent, the length of time soil and solvent are in contact while shaking or soaking, and the temperature during this process.

To interpret the results of such analysis there must be adequate correlation with field behaviour.

Owing to the difficulty of interpreting the results of chemical analysis alternative methods have been proposed for the assessment of plant nutrient status of soils. These include Mitscherlich's Pot-culture method by which the response of crops to increasing applications of a particular nutrient is measured, Neubauer's Seedling method whereby seedlings grown on the soil are analysed and the percentage of phosphorus and potassium determined, and the " Aspergillus niger " method which depends upon the growth made by a mould in nutrient solutions from which the nutrient to be assessed has been omitted but to which definite quantities of the soil have been added.

For some time the plant itself has been used for diagnostic purposes by the observation of discolorations of vegetative parts. In conjunction with the assessment of the nutrient status of leaf tissues and of the soil, considerable use may be made of this method.

WEATHER

RAINFALL IN THE BRITISH ISLES

THE distribution of annual rainfall is shown in Fig. 1. Comparison of this rainfall map with a physical map of the country shows that average annual rainfall increases almost

FIG. 1. Annual rainfall. Adapted from "Rainfall Atlas of the British Isles."

directly with height. Apart from physical features rain increases from east to west, as shown by the rainfall of place along the south coast: London 24 inches, Brighton 28 inches, Bournemouth 32 inches, Plymouth 37 inches, and Falmouth 44 inches.

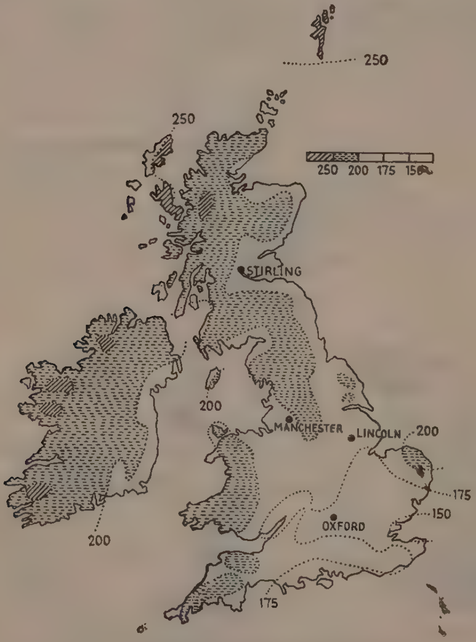


FIG. 2. Areas of highest rainfall.

Rainfall in the wettest areas can be ten times that of the driest. The wettest places, the summit of Snowdon and the head of the River Garry in Inverness-shire, have an average annual rainfall of 200 inches; the driest part, the Thames estuary, averages 20 inches.

The difference in the number of " rain days " is not so great. A " rain day " is one on which there is one hundredth of an inch of rain or more, either by day or night. Places with most rain days are confined to higher land and to the west (Fig. 2). At most places one-quarter of the total rain for the year is contributed by the ten wettest (not necessarily consecutive) days, and half the annual total by the 30 wettest days.

Due to the frequent changes of weather over the British Isles and the prospects of heavy rains at all times of the year,

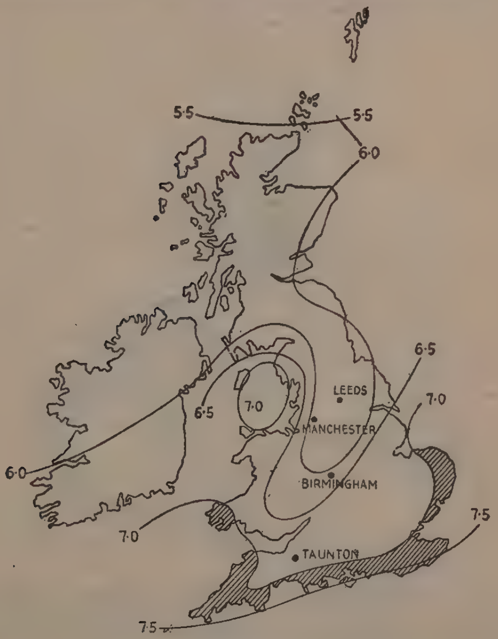


Fig. 3. Average sunshine in June (hours per day).

rainfall varies little from season to season although for any given month it can vary astonishingly either side of the average for that month.

Even in the driest years any group of four consecutive months gives not less than about one-tenth the average annual rainfall at any place. If this minimum has been recorded in any four-month period, then the next four months can be relied upon to give at least another two-tenths,

FIG. 4. Average sunshine in December (hours per day).

making three-tenths, or just under one-third, of the average annual rainfall in the eight months.

There are seldom more than 20 consecutive days completely dry in the extreme north of Scotland and north-west Ireland. Periods of 40 days without measurable rain have occurred only locally in eastern, central and south-eastern districts of England. Once a year, on average, there is an absolute drought (more than 15 days without rain) in the south of England from Somerset and Gloucester to Suffolk and Kent. In north-east Scotland this occurs only once in five years.

SUNSHINE

In the south, summer sun amounts to about 50 per cent. of the possible; in the Midlands and north amounts fall

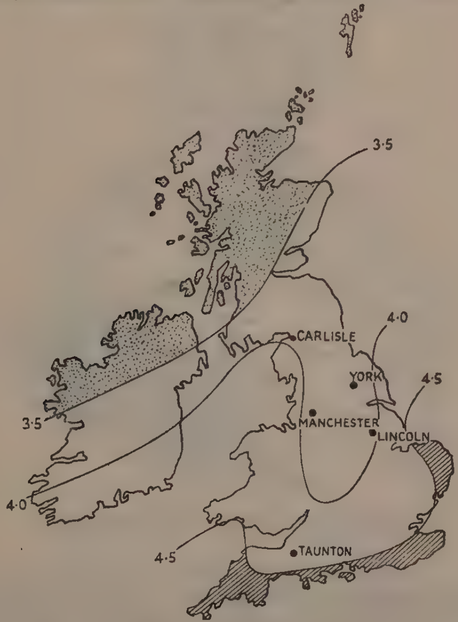


Fig. 5. Average sunshine for the year (hours per day).

below 40 per cent of possible. In the winter it is much lower—in the region of 20 per cent. of possible or less. Figs. 3, 4 and 5 show the average sunshine for the British Isles in summer, winter and for the year. These maps should be

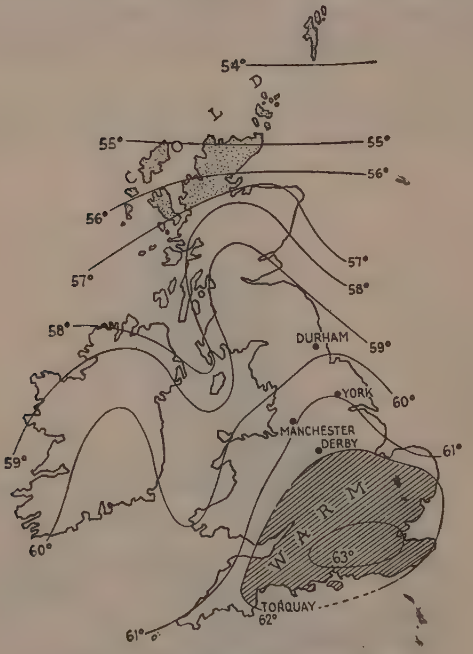


Fig. 6. Mean temperature in July.

compared with those in Figures 6 and 7 which show the mean temperature distribution for July and January. It will be seen that the sunniest areas are not necessarily the warmest.

TEMPERATURE

The distribution of July and January mean temperatures is shown in Figs. 6 and 7. In July, the farther north the

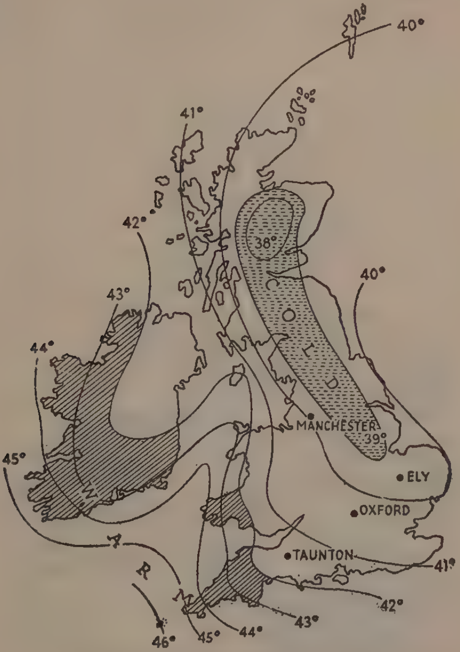


FIG. 7. Mean temperature in January.

lower the temperature. This is not so in winter. It is an exceptional winter when there are not periods of easterly or south-easterly winds bringing to the eastern half of the

British Isles air having its origin in the sub-zero regions of eastern Europe or Russia. Frequently extreme western districts escape these winds and enjoy winds from the

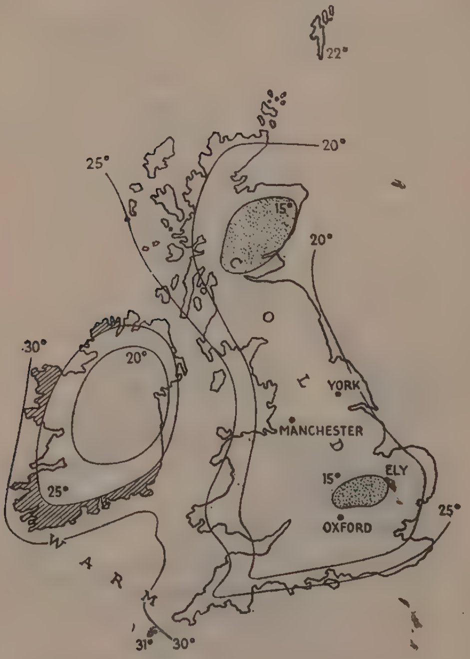


FIG. 8. Average coldest night of the year.

Atlantic, the temperature of which never falls below 50° F. at the latitude of Scotland.

The temperature distribution on the average coldest night of the year is shown in Fig. 8.

BUCHAN'S COLD AND WARM SPELLS

Cold.		*Warm.*	
February	7–14	July	12–15
April	11–14	August	12–15
May	9–14		
June–July	29– 4		
August	6–11		
November	6–13		

FIG. 9. Highest temperatures on record.

More significance is attached to these dates than Buchan intended. He claimed only that there was a tendency for cold and warm spells to occur at the times given, and this only in south-east Scotland.

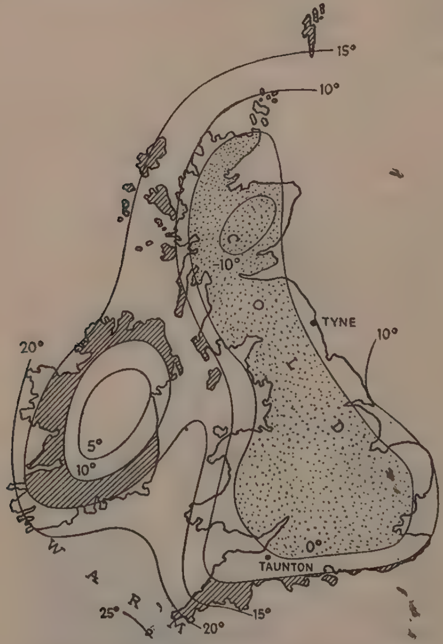


FIG. 10. Lowest temperatures on record.

BEAUMONT PERIODS AND POTATO BLIGHT FORECASTING

A Beaumont critical period is one of 48 hours during which temperatures do not fall below 50° F. and the relative

humidity is 75 per cent. or above on all 48 of the hourly observations. Outbreaks of Potato Blight may be expected within 21 days of such a period.

The blight warning service of the N.A.A.S. is based on hourly observations of temperature and humidity made at many places up and down the country. The warning service has achieved a high degree of accuracy and correct advice on the timing of spraying is given in most districts. The warnings are for guidance only; whether or not spraying is done depends also on local factors, the state of the crop and the altitude and exposure of the field in relation to the weather station at which the area observations were made.

WIND AND SHELTERBELTS

Inland wind direction tends to follow the valleys and often the valley floor suffers greater exposure than the middle and upper slopes on either side.

A dense impenetrable shelterbelt gives the greatest reduction in wind force but this is limited to a relatively narrow strip in the immediate lee of the belt. At a distance from the belt of about 20 times its height, there is little or no sheltering effect. A dense belt also gives rise to turbulence with damaging down-draughts and whilst most suitable for sheltering stock is unsuitable for protecting crops.

A semi-permeable belt reduces wind speed by half at a distance of about 15 times its height. There is some slight sheltering effect at a distance of about 30 times its height. It is thus most suitable for sheltering crops. For this purpose the cross-wind length of the shelterbelt should be at least 20 times its height.

During a blizzard snow drifts form in the immediate lee of a narrow but dense windbreak but if made wider and slightly permeable this danger is reduced. Windbreaks erected to prevent snow drifting in roads should be set back from the road a distance of at least 5 times their height.

FACTS ABOUT RAIN

One inch of rain is about 3,630 cubic feet per acre. This is 22,622½ Imperial gallons or approximately 101¼ tons. 12 inches of level snowfall are approximately the equivalent of 1 inch of rain.

Crops yielding three tons of dry matter per acre use the equivalent of nine to twelve inches of rain. Sugar beet and

similar crop requirements are, on average, 11 inches of rain during the whole growing period.

After a critical point, rain induces the growth of straw rather than grain.

Very generally, areas having not more than 30 inches of rain a year are favourable to a wide range of crops. Most areas with more than 60 inches of rain are agriculturally "sub-marginal." Also very generally, the wetter the district the lighter the soil.

A dull, wet, drizzly day is unlikely to give more than a quarter of an inch of rain. Falls of over one inch are infrequent even on the wettest days unless the weather is also thundery.

Present scientific opinion is that most rain in temperate latitudes starts in the form of ice crystals in the top part of the cloud which is in the freezing level. The ice crystals fall through the cloud and gather moisture, as ice. If the air temperature below the cloud is above freezing the ice crystals melt into rain drops. Otherwise they fall as snow. In certain circumstances rain will fall from clouds whose tops are not freezing. In these instances the water droplets within the cloud must be of critical size and the turbulence within the cloud sufficient for the droplets, too small to fall on their own, to collide and coalesce to form rain drops.

It is the violent updraughts within cumulo-nimbus clouds which cause hail. Ice crystals fall through the cloud, collecting moisture and growing, but then meet the full force of the updraughts in the cloud and are carried upwards to a level from which they again fall. This process is repeated several times and throughout the original ice crystals collect moisture. Eventually, as hailstones, they become too heavy for the strongest updraughts and fall out of the cloud.

Attempts to increase rain and snow cover artificially have been successful in Europe and America. Some attempts to suppress hail have also been successful.

There are two types of drought:—Absolute drought when there are 15 or more successive days without rain, and partial drought when there are 29 or more successive days with a total rainfall averaging not more than one hundredth of an inch a day.

Agricultural drought, the stage at which water shortage results in actual damage to the growing crop rather than just

a check in growth, may set in during what is technically only a period of partial drought.

In growing plants water is extracted from the soil by the roots, moves upwards through the plant and is given off as water vapour. This process is known as transpiration. During summer months, when plant growth is rapid, natural rainfall is frequently not enough to make up for the water lost from the soil by evaporation, drainage and transpiration and a state of agricultural drought exists. Irrigation must start well before this state is reached.

Irrigation need, both to prevent agricultural drought and to ensure maximum growth, is computed from data obtainable from the N.A.A.S. or from the Agricultural Branch of Meteorological Office. The number of years in ten in which some irrigation is required to ensure maximum crop growth is shown in Fig. 9.

FACTS ABOUT SUNSHINE

There is little evidence to show that the 11-year sunspot cycle gives rise to any corresponding weather cycle.

In December the sun is up for eight hours a day (though seldom seen for that time) in the south of England, and for six hours in the Shetlands. In June the sun is up for just over 16 hours in the south and for about 18½ hours in the Shetlands.

The solstice is the point at which the sun has moved farthest from the equator, north or south. The summer solstice gives the longest day around June 21st. The sun has then moved farthest north and is directly over the tropic of Cancer. The winter solstice gives the shortest day about December 21st. The sun is then farthest south and directly over the tropic of Capricorn in the southern hemisphere.

The equinox is the time when the sun is crossing the equator and day and night are equal in length. The spring equinox is about March 21st and the autumn about September 23rd.

The heat from the sun does not warm the air. The earth is heated and throws back the heat which can then be absorbed by the air.

The mean daily soil temperature at a depth of six inches in a south facing slope can, in summer, be two or three degrees higher than at the same depth in a north facing

slope. In spring the differences might be greater, the sun being relatively low in the sky. Thus a south facing slope may give an early bite but could also bring fruit trees into flower too soon, so making them more susceptible to later spring frosts.

FACTS ABOUT TEMPERATURE

Every rise of 300 feet above sea level gives a decrease of 1° F. in the average temperature.

Most farm crops in the British Isles make no substantial growth until the level of the mean daily temperature exceeds about 42° F. The rate of subsequent growth is closely linked by the amount by which the mean temperature exceeds 42° F. up to the optimum temperature which is somewhere between 60°–80° F. according to the type of plant.

The " growing season " is the period for which the mean daily temperature is above 42° F. There are generally as many growing days after July 31st as there are before. For every 50 feet of height above sea level the growing season is shortened by about two days; e.g., spring at 500 feet will be about 10 days later, on average, than at sea level for similar average temperature areas.

Thus for any region there is a height above which crops fail to make substantial growth and have too little time to ripen; e.g., wheat above 1,000 feet, oats and barley 1,500 feet. In most parts of the British Isles a height of 700 feet is regarded as critical for general farming, the growing season being cut by one month, starting, on average, two weeks later and ending two weeks earlier than surrounding sea level regions.

The air takes its temperature from the temperature of the earth or water over which it passes. The amount of water in soil affects soil temperature and therefore has a bearing on air temperature.

Water increases the heat conductivity of soil and in winter helps to transport heat to the surface from the warmer soil levels lower down. Thus the danger of sudden keen radiation frost on clear nights in spring is generally less if preceding weeks have been wet.

Wet soil takes considerably more heat to warm up to a given temperature than does dry soil. If the ground in spring is damp, the day on which it reaches the growing

temperature of 42° F. is much later than if the ground were dry. Ploughing snow into the soil at the beginning of the year increases the water content of the soil and delays the start of the growing season.

Air trapped in loose soil or in vegetation just above it prevents the flow of heat out of the soil into the air above and at night the air temperature will be lower than if no such insulating layer existed. During the day air trapped in the vegetation or loose soil prevents the sun's heat being transferred into the lower soil depths and the air temperature is somewhat higher than if no insulating layer existed.

The critical temperature at which milk turns sour is between 60° F. and 65° F. There is comparatively little danger during weather with temperature some degrees above the critical level provided the temperature is steady, but rapid temperature fluctuations around the critical level promote milk souring. During thundery weather the excessive temperature changes associated with such weather cause the damage.

The tissues and cell structure of most growing plants suffer no damage until the temperature falls below 30·4° F., 1·6 degrees below freezing point.

The temperature, high or low, at which the plant is killed is the Thermal Death Point.

Vernalisation, the pre-treatment of seed to influence plant growth and development, involves the subjection of the seed to temperatures little above freezing.

FACTS ABOUT FROST AND FROST PROTECTION

Frost is a fall in temperature below the freezing point of water, 32° F. or 0° C.

A ground frost is one when the temperature at ground level is 30° F. or lower.

There are two types of air frost: radiation frost which occurs on calm, clear nights, and wind-borne or advection frost which occurs only in winter when an easterly air-stream is coming from a frost-bound Continent. In a radiation frost it is usually only the air near the ground which is below freezing; the rise in temperature from the ground upwards can be as much as 10 degrees in the first 6 feet. In a wind frost the whole air mass above the earth is below 32° F. Winds associated with radiation frost are usually very light.

The damaging effect of frost is much greater if there is a wind. The temperatures in calm air (as in radiation frost) and with a wind speed of about 24 m.p.h. (as in a wind frost) which will give frost of similar severity, are given below:—

Term	Corresponding Temperatures° F. Calm Air	24 m.p.h. wind
Slight frost	32–27	32–31
Keen frost	26–21	30–29
Hard frost	20–11	28–26
Severe frost	10– 0	25–23
Very severe frost... ...	Below 0	Below 23

Kent invariably suffers badly from any wind frosts, the cold air being scarcely warmed by the narrow strip of sea. Further up the east coast the widening sea modifies the freezing east winds. Temperatures in the same air stream may be ten degrees below freezing in Holland and 15 degrees higher in Norfolk and some degrees higher at Tynemouth.

Cold air is heavier than warm air. During a radiation frost the cold air near the ground flows downhill like water, collecting in hollows and also against thick walls and hedges; much damage on sloping ground can be avoided by clearing such obstacles.

A thickly grassed orchard is more susceptible to radiation frost than is one with fallow soil. Ideally the soil should be compacted, not loose. On sloping ground grass will, in addition to preventing the flow of heat from soil to air, tend to hold up the downward flow of cold air from the site.

It is difficult or impossible to drain a natural frost hollow of its cold air. Damaging frosts in April and May are radiation frosts and the difference between a frost hollow and an open site means the difference between a killing frost and no frost at all.

Many crops, especially early potatoes, suffer less damage during a frost than during a quick thaw the following morning. In localities subject to late frosts sites facing away from the morning sun should be chosen for the more susceptible crops.

It is not uncommon for frost resistant plants to die of drought rather than frost during a period of severe wind

frost. The plant cannot absorb moisture from the frozen ground nor from the dry winds.

Plants protected from frost by straw or similar covering must be completely covered. Any exposed part is subject to lower temperatures and a greater risk of frost damage than if no covering is used at all. The straw provides an insulating layer which keeps the heat within the soil (and plant) but the air immediately above is correspondingly colder and the frost keener.

FROST PREVENTION

The three main principles of frost prevention are:—

(1) Adding heat; (2) preventing loss of heat; (3) circulating the cold air so that it mixes with warmer air above.

The above are applicable only in cases of radiation frost. Wind frost cannot be modified.

(1) Adding Heat. Heat may be added by oil heaters. Such heaters can be effective when the frost is not severe.

Radiation heaters burning liquid fuel under pressure are effective for small areas, one heater to one-quarter or one-third of an acre. This method is economical only for particularly valuable crops.

The soil itself is a large heat reservoir and special cultivation can liberate this heat. In England the practice is unlikely to be a commercial proposition.

Special irrigation is effective, particularly with potatoes and tomatoes. The plants are sprinkled with water as the frost sets in. The water freezes on the plants and in so doing releases latent heat (of fusion). This heat prevents the temperature of the ice falling below 32° F. for as long as water is applied. The water must be applied as long as the frost lasts and at a rate of about one-tenth of an inch an hour. The application of this amount of water, possibly on several successive nights, can give rise to other troubles and damage soil structure.

(2) Preventing Loss of Heat. Heat is not easily radiated away from the earth on cloudy nights and artificial cloud should theoretically prevent frost. Making smoke to this end—" smudging "—is effective in very limiting conditions.

(3) Frost prevention by circulating the cold air so that it

mixes with the warmer air above appears to be a method too costly for general use. In practice, large fans up to 30 feet in diameter are mounted horizontally facing the sky. Driven by tractors, the fans draw down the upper warm air which displaces the cold. A considerable area below each fan is warmed by several degrees in this way.

WEATHER FORECASTS

Short range forecasts—the weather for the next 24 hours and an outlook for the following day—may be obtained free of charge from the following meteorological offices of the Air Ministry.

(*a*) Forecasts obtainable at any time of the day or night.

London (Victory House)	HOLborn 3434
Aldergrove (nr. Belfast)	Crumlin 339
Bawtry	Bawtry 474
Croydon Airport	Croydon 7744
Dunfermline	Inverkeithing 266
Glasgow	RENfrew 3043
Gloucester	Gloucester 23122
Lyneham (nr. Chippenham) ...	Bradenstoke 283
Manby (nr. Louth)	Louth 2145
Manchester Airport	GATley 3211
Mildenhall	Mildenhall 2274
Nottingham	Nottingham 40000
Plymouth	Plymstock 2534
Preston	Preston 4602
Prestwick Airport	Prestwick 77256
Upavon (Wilts)	Upavon 86

(*b*) Forecasts obtainable from 9 a.m. to 5 p.m. Mondays to Fridays and 9 a.m. to 1 p.m. Saturdays.

Aberdeen	Dyce 331
Abingdon (Berks)	Abingdon 1408
Acklington (North'land)	Red Row 261
Bassingbourn (Herts)	Royston 2271
Binbrook (Lincs)	Binbrook 261
Birmingham	SHEldon 2441
Blackbushe (Hants)	Camberley 1600
Boscombe Down	Amesbury 421
Cardiff	Rhoose 343

Dishforth (Yorks)	Boroughbridge 421
Kinloss (Morayshire)	Forres 261
Leuchars (Fife)	Leuchars 271
Liverpool	GARston 2437
Marham (nr. King's Lynn)	King's Lynn 3141
Oakington (nr. Cambridge) ...	Cambridge 56441
Ronaldsway (Isle of Man)	Castletown 3311
St. Mawgan (Cornwall)	Newquay 2201
Shawbury (nr. Shrewsbury) ...	Shawbury 335
Southampton	Eastleigh 2341
Tangmere (W. Sussex)	Chichester 2643
Thorney Island (Hants)	Emsworth 2381
Turnhouse (Edinburgh)	Corstorphine 2351
Upwood (Hunts)	Ramsey 2294
Valley (Anglesey)	Holyhead 360
Wittering (Northants)	Stamford 2251
Wyton (Hunts)	Huntingdon 251

(Callers should ask for the Forecast Office)

For a regular series of weather reports or routine forecasts for any district, the Meteorological Office makes a charge which includes a registration fee and the cost of transmission of the messages.

LONG RANGE WEATHER FORECASTS

These are obtainable from private firms of weather consultants such as IMCOS Ltd. (International Meteorological Consultant Services), 200 High Holborn, London, W.C.1.

Farmer & Stock-Breeder also carries a special 7-day outlook designed for farmers and covering specific areas of the country.

CONSULTANT SERVICES

A separate branch of the Meteorological Office deals with matters of agricultural meteorology. Officers of this branch are stationed at the Provincial Headquarters of the N.A.A.S. at Bristol and Cambridge. In Scotland a specialist officer of the Agricultural Branch is stationed in Edinburgh and enquiries should be addressed to: The Superintendent,

Meteorological Office, 26 Palmerston Place, Edinburgh, 12 (Tel.: Caledonian 6561).

WEATHER LORE

The forecasting of the weather of the immediate future from such signs as grey or red skies, watery suns, haloes and "mares' tails" is not to be discredited, but such natural signs of changing weather can be insufficient, possibly misleading, if the broader and less local weather picture (as seen by the professional meteorologist) is not known.

Weather sayings which predict the weather for weeks ahead on the strength of a single observation are very suspect. An abundance of berries in winter is the outcome of the weather of the past growing season and present conditions, and there is little evidence that the weather of one season is directly related to that of the next.

The behaviour of animals, birds and insects can be a reasonably reliable guide for only a few hours, or even minutes, ahead.

DRAINAGE

LAND drainage works have two objects; to prevent or alleviate the flooding of those areas where such flooding would be injurious, and to provide suitable conditions in the soil for crop growth.

"Arterial drainage" comprises work on the major rivers and watercourses which are under the control of Drainage Authorities. "Field drainage" refers to work on under-drainage systems and smaller open channels and field side ditches.

ARTERIAL DRAINAGE

(*The notes in this section apply only to England and Wales*)

The major legislation is contained in the Land Drainage Act, 1930, as amended by the River Boards Act, 1948. A useful explanation of the Acts is contained in the leaflet "River Boards—A guide to their powers and functions," published by Her Majesty's Stationery Office.

The Drainage Authorities are River Boards, Internal Drainage Boards, and the Councils of Counties and County Boroughs.

River Boards have responsibilities, within their areas, in connection with land drainage, river pollution, fisheries, conservation of water and, in certain cases, navigation. Members of the Board are appointed by the Minister of Agriculture, Fisheries and Food, and by the Councils of Counties and County Boroughs within the Board's area. Apart from Government grants their main source of revenue is from precepts on County Councils and County Borough Councils.

For drainage purposes certain lengths of watercourse are under the control of the Board who may carry out maintenance and improvement works on them. These lengths are known as "Main River" and are marked on maps held by the Board. The Sea Defences of low lying areas are generally, but not always, the responsibility of River Boards. Where the importance of drainage merits it, certain areas within the River Board Area may be designated an

Internal Drainage District. Members of the Board are elected by owners and occupiers of land and property within the district who pay a drainage rate to the Board. Internal Drainage Boards select the watercourses for which they are prepared to accept responsibility and their powers and functions are broadly similar, within their district, to those exercised by River Boards.

The Council of a County or County Borough may, if it wishes, prepare and carry out drainage schemes for an area of land which, while capable of improvement by such works, does not justify the setting up of an Internal Drainage Board. Some Councils also have certain powers under local Acts.

DITCHES

The shape and size of a ditch depends on its function and the amount of water it has to deal with. There are wide variations in different parts of the country and in different situations. The dimensions quoted below are generally accepted as the minimum but there are exceptions.

Bottom width should, within reason, be as narrow as possible so that the depth and speed of the water will carry away debris falling into it. It must be wide enough to facilitate maintenance. Upland ditches are usually 1 ft. to 1 ft. 3 in. wide and lowland marsh ditches 3 ft. to 4 ft.

Depth should be sufficient to provide an effective outlet for existing or future drainage systems, and to discourage stock from walking into the ditch. The generally accepted minimum is 3 ft. to 3 ft. 6 in.

Bank slope depends largely on the type of soil. Banks may be practically vertical in " raw " peat, whilst in waterlogged sandy soil they may have to be at an angle to the horizontal of less than 30°. A useful rule for general application is to make the top width of the ditch equal to the sum of the bottom width and the depth ($T = B + D$).

Gradients should be as uniform as possible. Variations may alter the speed of flow of the water and cause trouble from erosion and siltation.

Spoil—Material dug out of the ditch should be placed where it cannot fall back or be pushed into the ditch by animals or cultivations. From the drainage point of view

it is preferable to spread it on the field adjoining the ditch, 3 in. to 6 in. thick, leaving a strip 18 in. wide against the ditch clear of spoil. Gutters must be cut through the strip of spoil wherever there are low places in the field to prevent surface water being held back from the ditch by the spoil. On boundary ditches the neighbour's permission will have to be obtained to spread the spoil in this way.

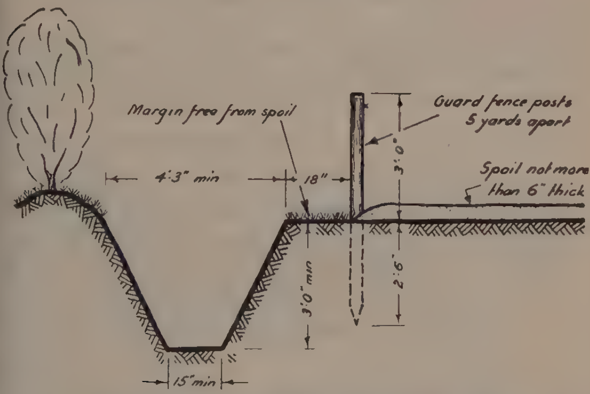


FIG. 11. Essential points in reconditioning a hedgeside ditch.

Excavation—Ditches should always be cleared to their original size, especially depth. Old underdrainage systems usually discharge within 6 in. of the original bottom and, by uncovering and renovating these outfalls, the whole of the old system may be revived. The original bottom may be assessed from the change in the colour of the excavated soil or by reference to the bottoms of bridges or culverts.

To use Table 3, find the nearest figure at the top of the table corresponding to the depth of the proposed ditch. Move vertically down this column until opposite the figure in the left-hand column nearest to the total of the top width and bottom width. The figure at this point gives the

QUANTITY OF EXCAVATION IN CUBIC YARDS PER CHAIN

TABLE 3

EXCAVATION IN CUBIC YARDS PER CHAIN

Depth (feet)

TOP WIDTH PLUS BOTTOM WIDTH (FEET)	1	2	3	4	5	6	7	8	9	10
5	6·1	12·2	18·3	24·4	30·6	36·7	42·8	48·9	55·0	61·1
6	7·3	14·7	22·0	29·3	36·7	44·0	51·3	58·7	66·0	73·3
7	8·6	17·1	25·7	34·2	42·8	51·3	59·9	68·4	77·0	85·6
8	9·8	19·6	29·3	39·1	48·9	58·7	68·4	78·2	88·0	97·8
9	11·0	22·0	33·0	44·0	55·0	66·0	77·0	88·0	99·0	110
10	12·2	24·4	36·7	48·9	61·1	73·3	85·6	97·8	110	122
11	13·4	26·9	40·3	53·8	67·2	80·7	94·1	108	121	134
12	14·7	29·3	44·0	58·7	73·3	88·0	103	117	132	147
13	15·9	31·8	47·7	63·6	79·4	95·3	111	127	143	159
14	17·1	34·2	51·3	68·4	85·6	103	120	137	154	171
15	18·3	36·7	55·0	73·3	91·7	110	128	147	165	183
16	19·6	39·1	58·7	78·2	97·8	117	137	156	176	196
17	20·8	41·6	62·3	83·1	104	125	145	166	187	208
18	22·0	44·0	66·0	88·0	110	132	154	176	198	220
19	23·2	46·4	69·7	92·9	116	139	163	186	209	232
20	24·4	48·9	73·3	97·8	122	147	171	196	220	244
21	25·7	51·3	77·0	103	128	154	180	205	231	257
22	26·9	53·8	80·7	108	134	161	188	215	242	269
23	28·1	56·2	84·3	112	141	169	197	225	253	281
24	29·3	58·7	88·0	117	147	176	205	235	264	293
25	30·6	61·1	91·7	122	153	183	214	244	275	306

amount of spoil to be moved assuming the ditch is full to ground level. Repeat the process using the dimensions of the ditch as it exists and subtract from the previous figure. This gives the amount of excavation required to recondition the ditch.

MAINTENANCE

Loose soil, washed off the banks of newly dug ditches after rain or frost, should be removed as often as necessary during the first twelve months. Thereafter weed growth should be cut and burned, and the silt shovelled out every year or at least every two years.

BOUNDARY DITCHES

Unless the Deeds of the property or local custom holds otherwise, it is usual to assume that the boundary ditch belongs to the owner of the hedge or fence. This means that the ditch is in the neighbour's field and the boundary of the property is at the top of the field bank of the ditch. It is usually necessary to obtain permission to enter the neighbour's land to maintain or recondition the ditch, and to spread the spoil on his land.

GUARD FENCING

A guard fence is required to protect the ditch in all fields which are, or are likely to be, grazed. In permanent pastures or long leys wooden posts and single strand of wire is generally sufficient although an extra strand may be desirable for small stock. Electric fences may be used effectively in short leys and for temporary grazing.

Plain wire must be used where the fence adjoins a public thoroughfare, elsewhere barbed wire is generally used.

Materials—Oak or other hardwood is probably the best material for posts but inclined to be expensive. Softwoods, such as " fir thinnings," can be quite serviceable if adequately treated with preservative, for example, creosoting by the " hot-cold steeping " method. Posts should be 5 ft. to 5 ft. 6 in. long, corner posts and straining posts should be at least 4 in. thick and intermediate posts at least 3 in. thick.

Wire should be galvanised, with barbs not more than 9 in.

apart. A roll of wire usually weighs about 1 cwt. and contains a length of 10 chains.

Design—The fence should be set 18 in. or more back from the top edge of the ditch bank. Intermediate posts, not more than 15 ft. apart, should be dug or driven into the ground, 2 ft. to 2 ft. 6 in. deep. Straining posts with struts notched and nailed to them should be provided wherever there is a major change in the direction of the fence and every 300 ft. on straight sections.

The single strand of wire should be 2 ft. 3 in. to 2 ft. 9 in, above ground depending on the type of livestock. It must be strained tight before stapling to the posts.

Maintenance—Posts should be tested periodically and rammed tight or replaced as required. Wire should be kept tight and replaced as soon as it becomes broken.

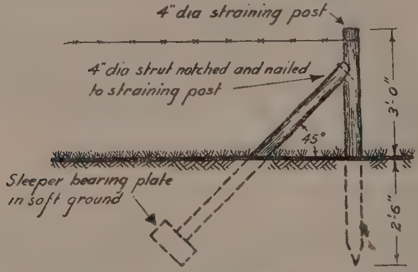


Fig. 12. Straining post and strut.

FARM CROSSINGS

There are many different kinds of farm crossings over ditches, some requiring professional skill for their design and erection. The " culvert " type is recommended for general use, consisting of a line of pipes in the bottom of the ditch with filling over.

The aim in making a farm crossing should be to cause the minimum obstruction to the flow of water in the ditch.

Pipes—The diameter of the pipe should be as large as possible having regard to the shape and size of the ditch,

with 9 in. diameter the minimum size. Twin or triple lines of pipes should be avoided. If the ditch is too shallow to take the size of single pipe required some other form of construction should be used.

CAPACITY OF CULVERT PIPES

TABLE 4

CAPACITY OF CULVERT PIPES

Diameter in inches	Cross sectional area in square feet	Maximum area acres
9	0·42	30
12	0·78	60
15	1·23	100
18	1·77	160
21	2·40	225
24	3·14	300
30	4·91	500
36	7·07	800
42	9·62	1140
48	12·57	1550

Any type of pipe may be used provided it is sufficiently strong and durable. Concrete pipes with " ogee " joints are the usual type but " second " quality glazed socketed stoneware pipes are also common.

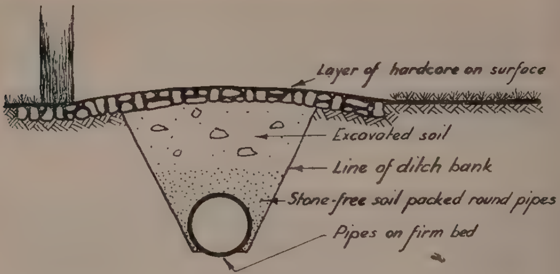


FIG. 13. Cross-section through gateway culvert.

Construction—The pipes should be laid on a firm bed to a gradient slightly greater than that of the ditch. Where spigot and socket jointed pipes are used hollows must be dug in the bed to accommodate the joints. The ditch bottom at the downstream end of the culvert should be slightly below the pipes.

The pipes should be packed tight with stone-free soil below and at the sides to give them adequate support. They must also be covered with a layer of stone-free soil, at least 6 in. thick, before the normal soil is put back, but if the cover is less than 24 in. the pipes should be surrounded with concrete. The filling should be rammed as it is placed, to reduce settlement, and built up slightly above ground level to prevent surface water standing in the gateway. A layer of hardcore or stones on the surface gives added support to farm traffic.

Headwalls are required at either end of the culvert to support the backfilling. Brick and concrete walls may be built vertical; stones laid dry require a slight slope, but turf must have a slope of at least 45° (1 to 1). Timber deteriorates too quickly to be considered a good material. The headwalls, except turf, should be built well into the bank at either side of the ditch and have an arch or lintel over the pipe to prevent the weight of the wall resting on, and displacing, the end of the pipe.

Length of the crossing depends on the type of farming practised in the district. The usual length is 15 ft to 18 ft., but where large machinery is used it may have to be up to 30 ft. The culvert should be long enough to allow sufficient room for machinery to turn into and out of the gateway without having to travel too near the headwalls.

DRINKING PLACES

Troughs connected to a piped supply are the most satisfactory way of watering stock. If a ditch has to be used special bays should be constructed which allow the stock access to a constant supply of fresh water but prevent them damaging the ditch or obstructing the flow.

Design—The usual form is a ramp down to water level with a post and rail fence across the bottom at the edge of the ditch. The ramp should be not less than 15 ft. wide at the water level and slightly wider at the field edge. The

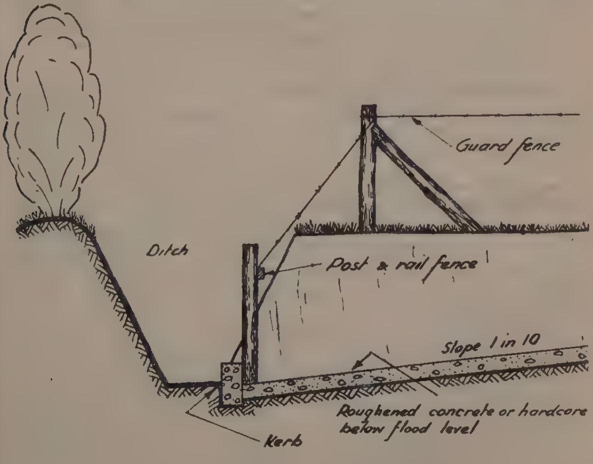


FIG. 14. Fencing for a drinking place.

slope should not be steeper than 1 in 10, and the floor below flood level of the ditch should be paved with hardcore or roughened concrete. The sides of the ramp should have the same slope as the ditch banks, and a guard fence along the top.

A concrete or wooden kerb across the bottom of the ramp supports the hardcore and prevents stones and debris being kicked into the ditch. The fence across the bottom must be substantial enough to restrain the stock and the rails so spaced that the animals can get their heads through to drink from the ditch.

UNDERDRAINAGE

Underdrainage refers to the network of artificial channels below the surface of a field by which surplus water is removed from the soil. The term includes:—

Tile drainage—A system of drains usually formed with clayware pipes, but may be applied to any other form of channel except mole drains.

Mole drainage—A form of drainage limited to clay soils where the channels are moulded in the actual soil and have no artificial lining.

Combined mole-tile drainage—A system used in lighter clays where the number of tile drains required is reduced by drawing mole channels shallower than, and across, the tile drains.

Layouts—The position of the drains and pattern of the system varies according to the particular problem of removing surplus water. In free-draining soils, where the predominant problem is to prevent the "ground water" rising into the root zone, the system usually consists of a series of deep parallel drains at regular intervals over the whole of the area. In heavy soils, where the surface water has difficulty in percolating through the soil, shallower drains are used with mole drainage or subsoiling. Where the wetness is due to water moving into the area, either through the soil or over the surface, a single drain or group of drains is used to intercept it.

The following table shows the number of pipes (12 in. long) required and the length of drain per acre (excluding mains) for various distances between drains.

TABLE 5

LENGTH OF DRAIN (EXCLUDING MAINS) PER ACRE FOR VARIOUS SPACINGS

Distance between drains yds.	Feet per acre	Chains per acre
5	2,094	44
7	2,073	31·4
11	1,320	20
14	1,040	15·7
22	660	10
44	330	5

TABLE 6

WEIGHT OF CLAYWARE PIPES (CWT.)

Diameter in.	Wt. per 1,000 cwt.
2½	31
3	40
4	55
6	88
9	170

TILE DRAINAGE

Materials—Clayware field drain pipes (tiles) should give a reasonably clear ring when stood on end and tapped with a light hammer or another pipe. They should be free from

globules of lime greater than say $\frac{1}{32}$ in. diameter, and from cracks or flaking extending into the body of the pipe which decreases their strength. The barrel should be reasonably straight, circular in cross section, with the ends cut square and smooth.

Concrete pipes, both "dense" and "porous," are an alternative to clayware. Unless well made with sulphate-resisting cement they are likely to deteriorate quickly in certain conditions and it is advisable to have the soil and soil water analysed before using this type of pipe.

Trenching—The main essentials are a narrow, shaped bottom into which the pipes can fit snugly, an even gradient and, wherever possible, a straight line. Spoil should be placed close to the side of the trench to facilitate backfilling.

Grading—An even gradient can be obtained by using "T"-shaped boning rods, sight rails and roving rod, or other recognised method. If these are not available a small canful of water poured into the trench from time to time as the work proceeds will indicate a continuous, but not necessarily uniform, gradient.

Laying—Pipes should be laid on a firm bed, fitted neatly and butted tightly together. In peat, running sand or other soft soil they may have to be laid on elm boards, ashes or similar material to preserve the alignment and gradient of the drain. Some drainers consider that the drain should be laid with a slight gap between the pipes, but there is a danger of silt entering the system with this method.

Backfilling—If necessary, the pipes should be packed at the sides ("blinded") with stone-free soil to stop them moving during backfilling. Unless some form of permeable filling is used it is traditional in many areas to place the top turf or soil over the pipe before bulldozing or ploughing back the spoil. The backfilling should be left slightly higher than the surrounding ground to allow for settlement.

Junctions between two drains are usually made by chipping pipes to form a neat joint and covering it with broken pipes. Purpose-made junction pipes are preferable for this work. Junctions of major importance can be made with a glazed socketed stoneware junction pipe together with an inspection cover.

Inspection chamber silt traps are desirable where several main drains join. The bottom should be about 12 in. below the outlet pipe; the walls should be impervious up to outlet level but may be " honeycomb " or pervious above and the top should be at, or above, ground level with a removable slab cover or manhole.

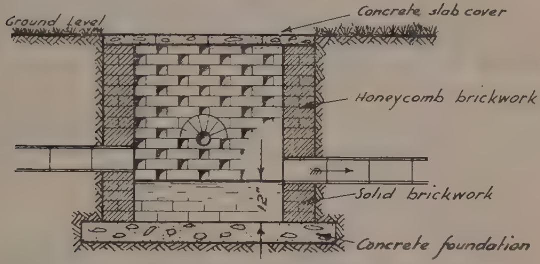


Fig. 15. Section of an inspection chamber.

Outfalls—Good outfalls are essential. The main points are a long durable pipe (glazed stoneware) at the end of the drain which discharges 6 in. above the bottom of the ditch and clear of the bank. The bank should be faced to ground

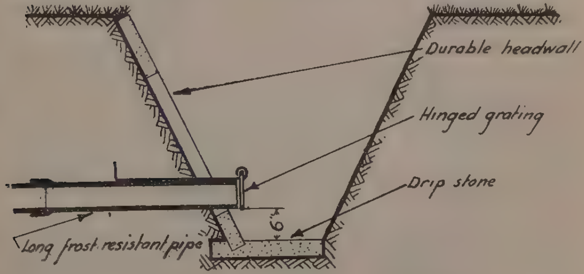


Fig. 16. Typical tile outfall.

level with a substantial durable headwall and the end of the pipe covered with a hinged grating to prevent vermin entering the drain.

Permeable filling—In many cases it is desirable to fill part or all of the trench above the pipes with some form of permeable material. On pure tile drainage work the material must be fine enough to prevent the fine soil particles reaching the drain and sealing the joints. Ashes, sand or straw are suitable for this. On mole or combined mole-tile schemes, the material forms the connection between the mole channel and the pipe main, and coarse gravel or clinker are best. Bushes may be quite satisfactory provided a sufficient quantity are used and they are laid with the butt ends on the pipe, the bushy ends at the top of the filling, and are well pressed down.

PIPED DITCHES

The replacement of open channels by piped drains requires careful thought and design and is a matter for the technician. The water-carrying capacity of the pipe is limited and much less than the open channel, whilst the possibility of flood damage and erosion during periods of heavy rain is increased. Deterioration and blocks in the pipe are not easily seen and may not become apparent until they have reached serious proportions.

Size of pipe required depends on the gradient, the area of land draining to the inlet, the type of soil and the drainage system. The minimum recommended diameter is 6 in.

Material—Clayware field drain pipes are suitable for drains up to and including 9 in. diameter, but above this size the diameter relative to the length makes them unstable, and glazed stoneware or concrete pipes should be used.

Installation—It is essential to find all the old under-drainage outfalls discharging into the ditch and connect them to the new pipe. It may be necessary to clean out the ditch for this purpose before laying the pipe.

The line of the drain should be straight or a series of straight sections, with an inspection chamber at all changes of direction. Similarly the gradient should be uniform or a series of gradients.

Pipes must be laid on a firm bed, and packed and covered with stone-free soil; the minimum cover should be 2 ft. 6 in. If a bulldozer is used to fill in the ditch care must be taken to see that the machine does not travel over the pipes until sufficient cover has been provided.

Sections where tree roots are likely to enter the pipe must be laid with impermeable pipes and the joints sealed.

Outlets and inspection chambers are similar to those described for tile drainage (see page 61) but in view of the importance of a piped ditch the better type of structure and material is justified.

Inlets—The object of the inlet structure is to prevent silt, debris or vermin entering the drain. The main requirements are a silt trap with a hard floor 12 in. below the bottom of the pipe, headwalls and wingwalls of durable material, a hinged grating with bars not more than 1 in. apart over the end of the pipe, and, on large streams or those carrying a lot of debris, a second screen or grating farther away from the pipe with bars about 2 in. apart.

Maintenance—The silt trap at the inlet and the inspection chambers must be looked at regularly and any silt removed, and the gratings cleared of twigs, leaves, straw and other debris as often as necessary.

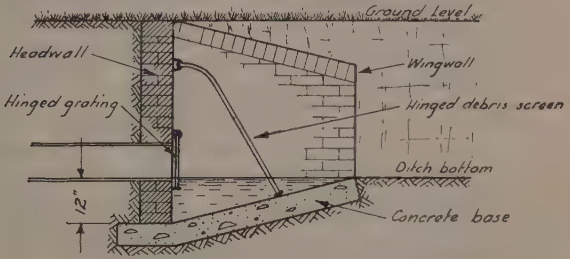


Fig. 17. Section of an inlet to a piped ditch.

MOLE DRAINAGE

Mole drainage is a cheap form of drainage which is relatively easy to carry out, but great care must be used in designing and carrying out the work as defects are very

difficult to put right. The operation consists of forming a circular channel in the clay subsoil by means of a " bullet " attached to a thin metal blade. The channels have to be drawn every few years; they usually deteriorate in 5 to 10 years, even in suitable soils, although in exceptional cases they have been known to last longer.

The object of mole draining is to form a reasonably stable channel in the clay subsoil and to crack and shatter the surrounding soil, forming secondary channels through which the water can reach this channel.

The system can only be used in a relatively stone-free soil with an adequate clay content. To leave a lasting and stable mole channel the work should be done in spring when the ground is dry enough on the surface to bear the machinery but still moist below; the subsequent drying out of the soil helps to " bake " the walls of the channel. To obtain the maximum cracking and aerating effect the work should be done in the autumn when the ground is at its driest.

Theoretically channels should be drawn uphill so that the cracks point in the direction of flow, but in practice it is doubtful whether the extra cost is justified except on land with a very little fall.

Layouts—Mole channels can only be drawn direct from a ditch if there is a continuous fall to the ditch and the last few feet of each channel is piped. They may be drawn over deeper mole mains which are drawn first and connected to the ditch with pipes. These systems are not very satisfactory as the outfalls have to be re-made every time the field is drained and, except for very temporary drainage are losing popularity in favour of the combined mole-tile system.

Present day mole ploughs are only capable of drawing channels parallel to the ground surface although small depressions such as plough furrows do not affect the alignment of the channel. Water standing in the channel causes rapid deterioration. Large quantities of water and high speeds of flow also have an adverse effect. The layout must be designed to avoid these dangers.

COMBINED MOLE-TILE DRAINAGE

The system consists of a skeleton layout of tile mains with mole channels drawn at a shallower depth across them. In heavy clays it provides a permanent system of mains for the

mole drains and in lighter clays, which are not suitable for pure mole drainage but nevertheless suffer from impeded percolation, it reduces the number of tile laterals required.

The precise layout depends on the surface undulations but generally speaking tile mains, 2 ft. 6 in. or more deep, are laid to a slight gradient across the general fall of the land and in all hollows where water is likely to stand in the mole channels. The maximum distance between tile mains in ideal conditions should be 5 chains (say 100 yards) and the spacing must be reduced on very slight or very steep falls, in areas with a high rainfall and on the lighter soils. The lowest main should be at least 11 yards from the ditch or field boundary.

Mole drains are drawn 19 in. to 24 in. deep and 3 to 5 yards apart in the direction of the general fall of the land, but where the fall exceeds, say, 1 in 25 it may be necessary to draw them slightly across the fall to prevent the flow of water reaching a speed or quantity sufficient to damage the channel.

Connection between mole channel and tile main—This is sometimes made by digging out wherever the mole channel crosses the main and making a "chipped pipe" junction. This method allows the silt from the mole channel to enter the pipe system and must be repeated whenever the mole channels have to be re-drawn. A simpler method is to fill the tile trench to within 15 in. of the surface with washed gravel or other suitable permeable material before replacing the excavated spoil. The mole channel then passes through the permeable filling and the connection is automatically formed whenever the mole draining operation is carried out.

GRANTS*

Grants are available to owners and occupiers of agricultural land towards the cost of field drainage work, including:—

(*a*) Reconditioning ditches and the necessary ancillary work such as hedge trimming, spoil spreading, protective fences, farm crossings and drinking places.

(*b*) Providing or reconditioning underdrainage systems, including tile drainage, mole drainage, combined mole-tile drainage and any other recognised methods.

* These notes refer only to England and Wales.

(*c*) Piping in ditches where this is desirable from the drainage point of view.

(*d*) Moorland gripping and other forms of surface drainage where these are of a permanent nature and are the recognised method of draining in the locality.

The present rate of grant is half the reasonable cost of the work, but it is subject to alteration.

The main conditions governing grant are:—

(*a*) The scheme must be approved *before* any work is started. In cases of exceptional urgency written authority may be given to commence work before the scheme is approved but without prejudice to subsequent consideration of the scheme.

(*b*) The work must be carried out in accordance with conditions laid down in the letter approving the scheme, and to the satisfaction of the appropriate officer of the Ministry.

(*c*) The scheme must be likely to remedy the drainage defect and have a reasonable life.

(*d*) The grant is based on the cost of a reasonable scheme, receipts for which must be produced.

(*e*) The probable enhanced value of the land after draining must justify the proposed expenditure.

(*f*) An accurate plan of the completed scheme must be produced for underdrainage work.

(*g*) Normal maintenance work is not eligible for grant.

Application for grant should be made on special forms obtained from the Ministry's Divisional Office. Full information is given in "Grants for Farm Drainage" obtainable at the Divisional Office.

MACHINERY

There have been many developments in field drainage machinery during recent years. Main types of machine are:—

DITCH DIGGING AND MAINTENANCE MACHINES

Dragline excavators are the most common machine for reconditioning ditches. They are capable of working on any sized ditch, but machines fitted with "side arm"

equipment and specially shaped bucket which is drawn along the ditch are best for small hedge side ditches. In the past these machines have tended to be rather heavy and not very mobile, but lighter and more mobile machines are now on the market. The bucket capacity is usually about $\frac{3}{8}$ cubic yard, and the output on normal ditches from 8 to 12 cubic yards per hour.

The light hydraulically operated grab bucket fitted to a normal tractor does useful work but has difficulty in cutting the banks to the desired slope and needs an additional man to control the bucket.

The back-acting scoop type of machine is usually a modification of the hydraulically operated trenching machine, although there are prototypes specially for ditching. They are mounted on normal farm tractors or on trailers, and are most useful for maintenance work although some models are capable of undertaking reconditioning work. Output varies considerably; a rough average is 2 to 3 chains per hour.

Scraper type scoops mounted on the front or rear of the tractor are popular with the small farmer who wishes to own his own machine. They usually have to travel backwards and forwards across the excavated spoil and so require reasonably good working conditions. They are more suitable for the marsh type ditch, being capable of dealing with widths up to 18 ft. and depths of up to 6 ft. Output is in the region of 2 to 3 chains per hour.

The revolving wheel or endless chain principle has possibilities for maintenance work, but reconditioning work entails travelling over the same length of ditch several times and perhaps running over the excavated spoil. Usually the chain revolves round a frame, capable of limited adjustment to suit the shape of the ditch, mounted on the side of a crawler tractor. Outputs of up to 30 chains per hour are possible when taking a cut 6 in. deep; maximum depth is about 3 ft. 6 in.

The Archimedean screw principle consists of a screw, revolving inside a casing, which draws up the silt and ejects it from a chute at the top end of the casing. Machines mounted on tractors and on pontoons which float in the watercourse have proved effective on marsh ditches. Usual output is from 6 to 8 ft. per minute with a maximum depth of 4 ft.

TRENCHING MACHINES

Plough type machines are usually reasonably cheap but have not proved completely satisfactory. They require a fairly heavy soil free from stone, and either several cuts are necessary to get to the required depth or the spoil is removed in such large pieces that backfilling becomes difficult. In recent machines the chute has been fitted with a conveyor and this may improve the performance. Maximum depth is about 3 ft. 6 in. in a series of cuts 6 in. deep, and the trench width about 8 in.

Back-acting machines may be either hydraulically operated scoops for use with normal farm tractors or special fittings in place of the drag-line jib of excavators. The larger machines are constructed to cut an even bottom to the trench but the smaller ones tend to leave a series of " scallops " unless the driver is very skilled. The spoil tends to be in large pieces and may be difficult to backfill but, on the other hand, most of these machines can work in fairly stony conditions. Depths of up to 9 ft. can be obtained with the larger machines and widths of trench up to 18 in. Outputs are about 1½ to 2 chains per hour.

Rotary wheel type of machines are very useful in soils which are reasonably free from stone. They can usually cut the trench to line and gradient, and deliver the spoil in small crumbs which can be easily put back into the trench. Maximum depth is about 3 ft. 6 in.; widths 8 in. to 9 in., and output 2 to 3 chains per hour.

There are several variations of the endless bucket chain type of machine. The larger contractor's machine can deal with a certain amount of stone, but the smaller types built on to a wheel tractor usually require soils reasonably free from stone. Depths of up to 5 ft. can be obtained and widths from 8 in. to 15 in. Outputs are in the region of 2 to 3 chains per hour.

MOLE DRAINING PLOUGHS

There has been little development in these machines, although several small ploughs capable of being mounted on or drawn by wheel tractors are now on the market. The lighter machines are more suitable for sub-soiling every two or three years over a good system of tile drains than for

drawing long-lasting mole channels. Ploughs with long beams can negotiate small surface irregularities with less effect on the channel, but require a draw-bar pull of 10,000 to 20,000 lb.

GRIPPING MACHINES

Several types of machine are available for cutting surface grips for " hill draining," marsh draining, forestry, irrigation and similar work. Sections range from 30 in. top, 8 in. bottom and 24 in. deep, to 9 ft. top, 7 ft. bottom and 2 ft. deep.

MISCELLANEOUS MACHINES FOR DRAINAGE

Many general machines can be used for the ancillary work in connection with field drainage. Angledozers fitted to wheel or tracklaying tractors can be used for pushing the spoil back into tile trenches, and bulldozers for spreading the spoil from ditches. Hydraulically operated shovels attached to tractors can be used for handling permeable filling used on tile mains for mole drainage schemes, and tipping trailers are useful for carting and spreading the material in the trench.

Some of the rotary type of trenching machines have attachments for laying the pipes in the trench.

MANURES AND FERTILISERS

PLANT FOODS

MAJOR nutrients are those which crops require in quantities ranging from a few pounds to a hundredweight or more per acre. The three usually added by manures and fertilisers are *Nitrogen* (N), *Phosphorus* (P) and *Potassium* (K). *Calcium* (Ca) is required by all crops and is supplied when necessary on acid soils by additions of liming materials. *Magnesium* (Mg) is an essential major constituent of all green plants. Most soils contain sufficient magnesium for ordinary crop growth and it is supplied by farmyard manure and by composts; additions of magnesium salts are needed only under special conditions where a magnesium-deficiency has been diagnosed.

Micro-nutrients or trace elements although essential to crops are required in smaller amounts, usually less than a pound per acre of the element being necessary for satisfactory growth. *Boron* (B), *Iron* (Fe), *Manganese* (Mn), *Copper* (Cu), *Zinc* (Zn), *Molybdenum* (Mo) and *Chlorine* (Cl) all fall into the micro-nutrient class. Most soils contain sufficient trace elements, they are also present in organic manures and in some fertilisers. It is undesirable to make a general practice of applying trace elements unless an actual deficiency has been diagnosed by a specialist advisory officer; an excess of these elements may be toxic to crops.

Manures are relatively bulky substances usually derived from farm or other waste products. *Fertilisers* are more concentrated materials. Both fertilisers and manures provide one or more of the major plant foods. In addition bulky organic manures add organic matter which improves soil structure, aeration and drainage and helps crops to make better use of the nutrients, air and water in the soil. Both organic manures and fertilisers are needed in most modern farming systems, organic manures to maintain and improve soil condition, fertilisers to supply the *extra* nutrients needed to correct soil deficiencies and to replace nutrients removed by crops or lost in the drainage water. Both are essential and their use is complementary.

TABLE 7

APPROXIMATE AVERAGE PERCENTAGE COMPOSITION OF MANURES

	Nitrogen per cent.	Phosphoric acid (P_2O_5) per cent.	Potash (K_2O) per cent.	Moisture per cent.	Organic matter per cent. (very approx.)
Manure					
Cow	0·4	0·15	0·4	75–80	20
Bullock	0·5	0·2	0·6	75–80	20
Pig	0·5	0·2	0·5	70–75	25
Sheep	0·7	0·2	0·7	65–70	30
Horse	0·5	0·3	0·6	70–75	25
Liquid manure	0·1	0·1	0·4	98 approx.	less than 1
Night soil	0·8	0·4	0·2	80–95	5
Dried sewage sludges ... (very variable)	0·5–2·0	0·5–3·0	traces to 0·5	8–40	10–40
Poultry Manures (fresh)					
Hens	1·5	1·5	0·8	50–60	25
Ducks	0·8	1·4	0·6	50–60	25
Geese	0·6	0·6	0·8	70–75	15
Composts					
Crop wastes and dung (Indore) (dry basis data)	1·1	1·7	1·0	—	30–40
Town refuse compost ...	0·8	0·5	0·3	—	—
Straw compost	0·4	0·2	0·3	70–75	20
Fresh seaweed	0·2	very low	1·2	80	15

BULKY ORGANIC MANURES

Farmyard manure and other materials such as composts made from crop wastes are of very variable composition; individual samples vary in the plant nutrients they contain, both from farm to farm, and from season to season. Analytical figures should be interpreted cautiously. Both nitrogen and phosphorus in farmyard manure act slowly and it is wise to assume that not more than half will be available to crops in the year of application. Table 7 gives approximate analyses for many of the organic manures used on farms, particular samples used may contain either more or less plant food than is stated.

FARMYARD MANURE

The Ministry of Agriculture estimates that 50 head of mixed cattle produce 150–180 tons of manure per year. In making manures sufficient litter should be added to absorb all the water. Most straws and other wastes used as litter absorb about twice their own weight of water, peat moss, however, absorbs three times as much water as straw.

Nitrogen is easily lost as gaseous ammonia from farmyard manure at any stage during making, storage or spreading. Losses are reduced in both shed and heap by keeping it as compact as possible. Heaps should not be turned during storage. Manure carted into the field should be spread and ploughed-in *immediately* since much ammonia can be lost during even a few hours' exposure to the air.

Potash is lost from manure whenever liquid seeps away. Therefore sufficient litter should be used to absorb all urine; if extra straw is added and water must be used to promote decomposition, then through drainage should be avoided. Where heaps of manure are stored out of doors heavy rain may cause serious losses of both nitrogen and potash. Some protection should be provided either by building heaps under cover or by providing them with temporary roofing.

Organic matter losses are inevitable in producing manure or compost since the fermentation process oxidises part of the carbonaceous material present. Losses are minimised by keeping heaps compact and by avoiding unnecessary turning or movement of the manure.

Spreading—A cubic yard of manure in the heap weighs about 12 to 16 cwt. Table 8 gives the number of heaps into which 2 ton loads of manure should be divided to give a required rate of application.

TABLE 8

RATES OF DRESSING WITH FARMYARD MANURE

Distance of heaps apart yards	5 tons per acre	10 tons per acre	15 tons per acre	20 tons per acre
5×5	75	37½	25	19
6×6	53	26½	18	13
7×7	39	19½	13	10
8×8	32	16	11	8

Farmyard manure should be ploughed in immediately after spreading to avoid losses of ammonia and preferably several weeks before any further cultivations are given. This allows a tilth to form by weathering of plough furrows in heavy soils; also the manure decomposes to some extent and there is less interference with cultivations, harrowing and planting. Early applications of farmyard manure should involve no risk of loss of phosphate or potash from most soils before the crop is grown; some loss of nitrogen from autumn dressings may follow a mild and wet winter.

In planning manuring a practical assumption is that a 10 ton per acre dressing of farmyard manure supplies 1·0 cwt. N, 0·5 cwt. of P_2O_5 and 1·0 cwt. K_2O. The potash is usually fully active but much of both nitrogen and phosphate is present in slow-acting forms; not more than half the nitrogen applied is likely to benefit a first-year crop. All bulky manures give best returns with crops which respond to improvements in soil condition, e.g., vegetables and market-garden crops. Potatoes, sugar beet and other roots give good increases in yield from farmyard manure even when full fertiliser dressings are applied as well; smaller gains result from manure given to cereals which have received fertiliser. When applied to grassland much nitrogen may be lost, extra yields of grass are due only to the plant nutrients supplied by the manure since it cannot be incorporated with the soil to improve structure.

When ordinary dressings of farmyard manure (5–15 tons per acre) are used there is no reason to reduce the normal fertiliser nitrogen dressing since the manure allows the crop to benefit from extra nitrogen. Phosphate and potash fertiliser dressings given when farmyard manure is applied may be reduced below the amounts needed when no manure is used.

LIQUID MANURE

Liquid manure comprises urine from stock and the effluent resulting from washing down sheds. Where possible this liquid should be saved since it contains appreciable amounts of potash besides small quantities of nitrogen and phosphate. It may be applied to arable land before sowing or to grassland from which hay will be taken. When liquid manure cannot be applied to the land it may be conserved by pumping over heaps of straw to be rotted down in yards or out of doors.

STRAW AS AN ORGANIC MANURE

Straw used on the land supplies some potash and a little phosphate but is deficient in nitrogen.

Where extra straw is used as litter in yards it may be necessary to add water to promote satisfactory decomposition; it is also a good plan to add inorganic nitrogen fertiliser (at the rate of 1 cwt. of ammonium sulphate per ton of excess straw) to assist rotting. Farmyard manure made in this way with extra straw will be poorer in plant nutrients per ton of product since much of the N, P and K in farmyard manure is derived from the feed given to the stock making the manure.

Useful organic manure is made by composting straw alone. For satisfactory rotting nitrogen must be applied and the heap kept sweet by adding 1 cwt. of ammonium sulphate and 1 cwt. of ground limestone per ton of straw; about 800 gallons of water are also needed. Such composts are undoubtedly of value in building up poor soils for intensive vegetable cropping, or on heavier land where it is difficult to maintain soil structure. Composts tested on agricultural crops have usually given smaller yields than farmyard manure made from the same quantity of straw. In practice it may be difficult to justify the high cost of labour involved in rotting straw or other farm wastes and before large-scale composting is undertaken small trials should be made.

When straw is ploughed-in directly after harvest the bacteria decomposing it lock up nitrogen in the process and the following crop may in consequence be deficient in nitrogen. *Extra* nitrogen fertiliser should therefore be applied in spring just before sowing at the rate of 1 cwt. of ammonium sulphate per ton of straw ploughed in. (Better use is made of the nitrogen by applying it to the crop sown in spring than by ploughing it in with the straw in autumn.)

FERTILISERS

Fertilisers are relatively concentrated materials containing at least several per cent. of plant foods. At the present time the tonnages of " organic " fertilisers (derived from plant or animal products) used are much smaller than the quantities of inorganic (mineral) fertilisers made by chemical processes or mined. Most of the " organics " sold are used in intensive market gardening or for glasshouse cropping, some mixed fertilisers used in ordinary agriculture contain a proportion of organic materials.

Straight fertilisers (or "straights") consist of one substance which provides one (and occasionally two) of the major nutrients nitrogen, phosphorus and potassium.

Compound or mixed fertilisers are made either at a factory, or on the farm, by mixing together appropriate straight fertilisers. Compound fertilisers provide either any two or all three of the major plant foods, they may be sold in powder form but are now usually granulated. Granular fertilisers have the advantage of storing well and are easy to spread. Once applied granulated and powdered fertilisers containing the same amounts of nutrients have similar values for crops.

ANALYSES OF FERTILISERS

Statutory declarations of analyses are usually to be found on the invoice. Analyses may also be printed on the labels attached to bags or on the bags themselves. Analytical figures give: (*a*) percentage of nitrogen (N), (*b*) percentage of phosphoric acid (P_2O_5) soluble in water, (*c*) percentage of insoluble phosphoric acid (P_2O_5), (*d*) percentage of potash (K_2O). These substances (N, P_2O_5 and K_2O) do not occur

in fertilisers as such but in combination with other components. The percentages of N, P_2O_5 and K_2O stated are chemically equivalent to the amounts of the elements nitrogen (N) phosphorus (P) and potassium (K) present in the fertiliser referred to.

Current Regulations governing the sale of fertilisers under the Fertilisers and Feeding Stuffs Act were issued in 1955 (Statutory Instrument 1955 No. 1673).

INORGANIC NITROGENOUS FERTILISERS

Sulphate of ammonia (or **ammonium sulphate**) usually contains 20·6 per cent. nitrogen (N); it is completely soluble in water and is quick-acting. The bulk of the material used is made synthetically by fixing nitrogen from the air, but some is a by-product of the gas and coke industry. Sulphate of ammonia has the disadvantage when used straight or as a component of mixed fertilisers that it makes soils acid.

" Nitro-Chalk " (15·5 per cent. N) is a proprietary granulated material consisting of a mixture of ammonium nitrate and calcium carbonate. The nitrogen is partly present as nitrate, partly as ammonium, it is all soluble in water and acts very quickly. This fertiliser must be kept dry in transit and storage; bags should not be opened until the fertiliser is required for use. " Nitro-Chalk " does not make soils acid.

Nitrate of soda (16 per cent. N) is mostly produced from natural deposits in Chile although some is now made synthetically. All the nitrogen is present in nitrate form and the fertiliser acts very quickly indeed. Nitrate of soda does not acidify soil. The sodium present is of definite value for mangolds and sugar beet but it is doubtful if it is of any use for other agricultural crops grown in this country.

" Nitra-Shell " (20·5 per cent. N) is a newly introduced proprietary granulated fertiliser. It appears to be similar to " Nitro-Chalk " (except that it contains more nitrogen) and to consist of ammonium nitrate and calcium carbonate.

Calcium cyanamide (about 20 per cent. N) is a synthetic nitrogen fertiliser of which only small amounts are now used in U.K. It has toxic effects on plants when freshly applied and has been used as a weed-killer. These effects disappear

as the material decomposes and it must therefore be applied to the soil some weeks before sowing a crop.

Potash nitrate (15 per cent. N, 10 per cent. K_2O) is produced from natural deposits in Chile and is used in market-gardening.

Other nitrogen fertilisers such as urea (46 per cent. N), anhydrous ammonia and " nitrogen solutions " are now used in the United States and in other countries. Up to the present these fertilisers have not been available to U.K. farmers in any quantity.

INORGANIC PHOSPHATE FERTILISERS

Mineral rock phosphates are mined in many countries but most of the supplies imported into this country come from North Africa. When used directly on the land rock phosphate should be ground finely so that practically all the material passes a 100 mesh B.S. sieve. (The Fertilisers and Feeding Stuffs Regulations (1955) require that the proportion of material passing this sieve be stated when rock phosphate is sold.) The soft rock phosphates from North Africa usually sold for direct application contain 26–29 per cent. of P_2O_5 which is insoluble in water. They are slow-acting and mostly used for swedes and turnips grown on acid soils in wet areas; they can also be used for grass and for fodder crops in these districts. Rock phosphates are of very little use on neutral soils, in dry areas, or for crops such as potatoes which require phosphate in a quickly acting form.

Superphosphate (approximately 18 per cent. water-soluble P_2O_5) is made by treating ground rock phosphate with sulphuric acid. Besides phosphorus superphosphate contains some calcium which may be of value on acid soils but the fertiliser has little ultimate effect on soil acidity. " Super " is suitable for all crops; for arable crops it should be applied before sowing since top-dressings are likely to be of little value. Top-dressing of grassland should be carried out in late winter or early spring before growth starts.

Triple superphosphate (about 47 per cent. water-soluble P_2O_5) is made by treating rock phosphate with phosphoric acid. Ordinary superphosphate contains gypsum as a residue from sulphuric acid treatment of rock phosphate, " triple " contains no gypsum. Since triple super is two and

a half times as concentrated as ordinary super it must be applied at proportionately lower rates; apart from this both kinds of superphosphate may be used for the same purposes. Both ordinary and triple super are available in granulated forms which are much easier to distribute mechanically than the powdered products.

Basic slag (usually 9–22 per cent. of total P_2O_5) is a by-product of the steel industry and contains both phosphate and lime. Slag has appreciable value as a liming material and 1 cwt. may be considered as roughly equivalent to two-thirds as much ground limestone. The phosphate in basic slag is insoluble in water and slow-acting and is not effective unless the material is finely ground, thus practically all of the slag should pass through a 100 mesh B.S. sieve. A valuation of the fertiliser effect of phosphate in basic slag is given by the solubility of the phosphorus in 1 per cent. citric acid solution. Slags containing practically all their phosphate soluble in citric acid are much more active than those which have only low citric acid solubilities. The Fertilisers and Feeding Stuffs Regulations (1955) require that both the fineness of basic slag and its solubility in citric acid should be stated. Basic slags are of most use for crops which have a long growing season. They may be less useful for crops which require the rapid stimulus of water-soluble phosphate to encourage root growth. Slags are particularly valuable for improving permanent and temporary grassland and, together with potash where necessary, for improving the growth of clover in pasture. They should be applied in winter or early spring to be washed into the surface soil by rain before growth begins.

Other phosphate fertilisers are only occasionally available in the U.K. in small quantities. Ammonium phosphate (11 per cent. N, 48 per cent. water-soluble P_2O_5) is a very concentrated quick-acting material which was imported during the war but has not been available in quantity as a " straight " fertiliser in recent years. It is used in the production of concentrated compound fertilisers.

POTASH FERTILISERS

Muriate of potash (50 per cent. K_2O or 60 per cent. K_2O) provides most of the potash imported in this country, the bulk is processed into compound fertilisers. Straight muriate

of potash is a difficult material to apply direct to the land since it has generally caked to a solid mass in the bags. When broken down it is sticky and, being hygroscopic, absorbs moisture from the air. Recently "pink potash" made by a flotation process has been introduced, this fertiliser is in small crystals but stores well, resists caking, and flows more easily through the mechanisms of distributors. All potash needed by arable crops should be applied before sowing; dressings for grassland may be given in winter or early spring.

Sulphate of potash (48 per cent. K_2O) is generally made by treating muriate of potash with sulphuric acid and is more expensive than the muriate. It is preferred by horticulturists and by glasshouse growers since the chloride provided by muriate of potash may raise the salt concentration of the soil to undesirably high levels where intensive cropping and very heavy manuring is practised. There is much less risk of chlorides accumulating under ordinary arable cropping conditions and for such purposes the higher price of sulphate as compared with muriate of potash would be difficult to justify.

Kainit and potash salts (12–30 per cent. K_2O) have been marketed in this country from time to time in recent years. They contain appreciable quantities of sodium salts and are particularly useful for sugar beet and mangolds when they can be obtained at satisfactory prices. Magnesium salts present in some of these lower-grade potash fertilisers may be valuable in areas where magnesium deficiency occurs.

Nitrate of potash or **saltpetre** is not identical with the "Potash Nitrate" imported from Chile as it contains a little less nitrogen and much more potash (about 40 per cent. K_2O). The small supplies which may be available are usually used by horticulturists.

Other sources of potash are only on a very small scale although they may be important locally. Wood ashes may contain from 2 to 5 per cent. K_2O. Seaweed ashes or kelp contain considerably higher percentages of potash and where seaweed itself is used on the land much potash may be applied. Flue dusts from iron and steel manufacturing processes occasionally come on to the market, they contain from 5 to 15 per cent. K_2O; it is important that they should be free from impurities such as cyanides, sulpho-cyanides and sulphides which are poisonous to plants.

ORGANIC FERTILISERS

Organic fertilisers are derived from plant or animal products. The merits claimed for " organics " are: (1) The plant nutrients being usually in organic combination are not water-soluble and are slowly released as the fertiliser decays in the soil. This process protects the nutrients from losses by leaching and releases them at a rate which may match crop requirements. (2) Since organic fertilisers contain little or no soluble salts they may be applied at very heavy rates without much risk of the injury to root growth which would be likely if inorganic fertilisers were used to supply the same amounts of plant nutrients. Being very costly per unit of plant food these materials are generally used in intensive market gardening and horticulture. They may be less economic for use in ordinary agriculture.

ORGANIC NITROGEN FERTILISERS

Hoof and horn meals, hoof meal, horn meal (12–14 per cent. N) can be obtained coarsely or finely ground. The finer grindings release nitrogen quite quickly when the soil is warm. They should be applied before planting or sowing.

Dried blood (12–13 per cent. N) must be dried carefully to avoid charring and to secure a satisfactory product. It acts very quickly and is much used in glasshouse work.

Shoddy—The quality of shoddy depends on the proportion of pure wool and other wastes present. Analyses may vary widely from 3 to 12 per cent. N and it is wise to buy on the basis of the analysis of particular batches.

Leather wastes may contain several per cent. of N but unless they are processed into genuine leather fertiliser meals the nitrogen is so slowly available that they are of little value.

ORGANIC PHOSPHATE FERTILISERS

Bone meals are made by grinding bones finely and may contain from 3 to 4 per cent. N and from 20 to 24 per cent. insoluble P_2O_5. The nitrogen in bone meals is active but the phosphate acts quite slowly and is most useful on acid soils; on soils with a reserve of lime the phosphate may act very slowly indeed.

Steamed bone meals and flours are made by steaming bones to remove fats and materials for making glue, a good deal of the nitrogen is also removed. Gentle steam extraction gives a product usually termed " steamed bone meal." " Steamed bone flour " is made by fine grinding of bones which have been intensely steamed. Both kinds of products contain 0·5–0·8 per cent. N and 26–29 per cent. insoluble P_2O_5. The phosphate in finely ground steamed bone flours may be expected to act more quickly than phosphate in coarser bone meals.

Meat and bone meals (often called " meat guano " or " tankage ") are made from meat and bone wastes, the analyses varying according to the raw materials used. The usual range of analyses is 3–7 per cent. N and 9–16 per cent. insoluble P_2O_5, the nitrogen they contain tends to be more quick-acting than the phosphate.

Fish meals and fish manures (sometimes called " fish guano ") are made from mixed waste products of fish processing. They may contain from 7 to 14 per cent. N and from 9 to 16 per cent. of insoluble P_2O_5.

Other organic fertilisers are imported into this country or are processed here. They are less important than the materials listed above and may comprise skin and bone meal, castor meal, cocoa meal, bird guanos. They should be judged by comparing their analyses and prices with those of the more common organic fertilisers.

POTASH IN ORGANIC FERTILISERS

The only true organic fertilisers containing appreciable amounts of potash are *bird guanos* (excreta of birds). Potash does not appear in organic combination in fertilisers and any potash which organic fertilisers may contain will be of much the same value as potash in ordinary muriate or sulphate.

COMPOUND FERTILISERS

Mixed or compound fertilisers contain two or three of the essential nutrients (nitrogen, phosphorus and potassium) and are usually made by mixing the " straight " materials described above. Compounds are intended to contain N, P_2O_5 and K_2O in ratios which suit certain crops and soils,

they also save labour in applying straight fertilisers separately. Most factory-made compounds are now sold in granulated forms which are much easier to store and to spread than the corresponding powders. Commercially-made powders are usually treated with conditioners or fillers (which themselves are generally of little or no value as fertilisers), thus giving the mixture a friable condition.

PROPRIETARY COMPOUND FERTILISERS

The National Compound Fertiliser scheme which provided farmers with a limited range of compounds having analyses which were agreed between the Trade and the Ministry of Agriculture has been abandoned and there are now several hundred proprietary compound fertilisers with different names or numbers on the market. While some of these are designed for purely local purposes the majority contain N, P_2O_5 and K_2O in ratios similar to those in the last range of National Compounds. On most farms there is no need to use a large number of compound fertilisers. By careful examination of the cropping system used, the type of soil, the climate, and the previous cropping and manuring, a farmer may, in collaboration with his District Advisory Officer, decide on a very few analytical ratios which will serve his needs. In recent years many fertilisers have been produced in more concentrated (" high analysis ") forms, the total of the percentages of N, P_2O_5 and K_2O being higher than in the older type of fertiliser intended for the same purpose.

PLANT FOOD RATIOS

Most manufacturers now state on their price lists, and on bags of fertilisers, a " plant food ratio " which expresses the ratio of the percentages of N, P_2O_5 and K_2O in the fertiliser, usually taking % N (or sometimes % P_2O_5) as unity. The purpose of the plant food ratio is to indicate to the purchaser the type of compound being offered. Any one of a group of fertilisers having similar plant food ratios will normally be suitable for one purpose, the quantity applied being varied according to the *actual* percentage of nutrients present.

For example, two fertilisers with very different percentage compositions are:

	N per cent	P_2O_5 per cent	K_2O per cent
A ...	7	7	10·5
B ...	12	12	18

Both have the same plant food ratio $\%N : \%P_2O_5 : \%K_2O$ being equal to $1 : 1 : 1\frac{1}{2}$ and they would be equally suitable for any particular crop, but rates of application must be adjusted according to total analyses. If 10 cwt. per acre of compound A were needed, then only 6 cwt. per acre of compound B would supply about the same amount of plant nutrients. Table 9 lists a few current compound fertilisers which are likely to provide for the needs of most crop and soil conditions. Examples are given of both " ordinary strength " and " higher analysis " materials having roughly the same plant food ratios.

USING COMPOUND FERTILISERS

Before selecting a compound fertiliser the likely needs of the crop and the particular field must be estimated. This requirement may be expressed in terms of cwt. per acre of N, P_2O_5 and K_2O or in " units " (hundredths of 1 cwt.) of these nutrients; from these figures the appropriate plant food ratio ($N : P_2O_5 : K_2O$) is calculated and, using the list of ratios printed in manufacturers' price lists, a suitable compound fertiliser selected. Rates of application are settled by dividing the amount of N (or P_2O_5) in cwt. per acre, which is to be applied, by the % of N (or $\%P_2O_5$) in the fertiliser chosen, and multiplying the result by 100 to give the required dressing of compound fertiliser in cwt. per acre. Thus, if 1·0 cwt. of N per acre is needed, together with 1·0 cwt. P_2O_5 and 1·5 cwt. K_2O, a fertiliser containing 7% N, 7% P_2O_5, 10·5% K_2O should be applied at:

$$\frac{1{\cdot}0}{7} \times 100 \doteq 14{\cdot}3 \text{ cwt./acre}$$

If the plant food ratio of the compound has been correctly chosen the right amounts of phosphate and potash will automatically be applied by calculating only the correct amount of nitrogen to be given.

TABLE 9

EXAMPLES OF CURRENT COMPOUND FERTILISERS

Compound Fertiliser Type	Plant Food Ratio $N : P_2O_5 : K_2O$	Ordinary Strength N %	Ordinary Strength P_2O_5 %	Ordinary Strength K_2O %	Higher Analysis N %	Higher Analysis P_2O_5 %	Higher Analysis K_2O %
A	1 : 1 : $1\frac{1}{2}$	7	7	10·5	12	12	18
B	1 : $\frac{3}{4}$: $\frac{3}{4}$	9	7	7	11·25	8·75	8·75
C	1 : $2\frac{1}{2}$: $2\frac{1}{2}$	4	10	10	5	12·5	12·5
D	1 : $1\frac{1}{2}$: 1	6	9	6	8	12	8
E	1 : 1 : 2	7	7	14	—	—	—
F	1 : $\frac{3}{4}$: 2	—	—	—	9	6	18
G	1 : 2 : 0	6	12	0	9	18	0
H	0 : 1 : 1	0	13	13	0	16	16
I	0 : 1 : 2	0	10	20	—	—	—

Farmers in doubt about the fertiliser needs of their crops or the fertility status of their soils, or who are not familiar with this way of choosing compound fertilisers, should seek the advice of the District Advisory Officer.

MIXING FERTILISERS ON THE FARM

Most proprietary compound fertilisers are made by mixing sulphate of ammonia, superphosphate and muriate of potash. Farmers who buy these ingredients for mixing will generally find the home-made mixtures are cheaper than the equivalent purchased compound, but they may be more difficult to handle and distribute than granulated materials. Farm-made mixtures are liable to set if they stand for any length of time and must be broken down before they can be applied, it is best to make up as much of a mixture as is needed and to apply it straight away. Setting can be reduced by introducing conditioners such as steamed bone flour but the cost of the mixture may then be raised and the advantage of home-mixing lost.

Mixing must be thorough and the ingredients should be broken down and sieved beforehand. Probably the best way of mixing is to put ammonium sulphate, superphosphate and muriate of potash into a dry concrete mixer and to run the machine for a couple of minutes. Alternatively appropriate quantities of "straights" may be mixed with shovels on a dry floor.

Alkaline materials like lime or basic slag should not be mixed with ammonium sulphate since ammonia will be lost. Both lime and basic slag if mixed with superphosphate causes "reversion" of water-soluble phosphate to an insoluble state.

Nitrates absorb moisture and make powdered mixtures sticky, they must *never* be mixed with organic materials as there is risk of fire.

The following materials must *not* be mixed with superphosphate, ammonium sulphate, ammonium phosphate or triple superphosphate:

Basic slag; "Nitro-Chalk" or "Nitra-Shell"; liming materials of any type; wood ashes; sewage sludges containing lime; nitrate of soda or nitrate of potash.

FERTILISER REQUIREMENTS

NUTRIENT DEFICIENCY SYMPTOMS

When crops are *grossly* deficient in one or other nutrients, they often exhibit symptoms by which the deficiency may be diagnosed. When such symptoms appear the shortage is so serious that yields will be much reduced and it is probable that the land has received too little of the particular nutrient for a considerable period.

Nitrogen deficiency causes poor growth of all crops except legumes. The plants are short, thin and the leaves pale green or yellowish-green in colour. Later in the season nitrogen deficiency may cause purple, blue and red colorations of the older leaves.

Phosphorus deficiency is easily recognised in young cereals; the plants and stems have a bluish-purple colour, in extreme cases the tips of the leaves may die. In other crops phosphorus deficiency may produce no characteristic colours; generally the plants are small and the leaves have a dull bluish-green colour, potatoes have an upright spindly habit of growth; mangolds, sugar beet and swedes are dwarfed. Where the deficiency of phosphate is not very acute deficiency symptoms may disappear if warm, wet weather sets in.

Potassium deficiency in cereals is most common in a dry, cold spring. The tips of the leaves yellow and may wither and die; new leaves formed in better growing conditions may be free from symptoms. Potatoes are very susceptible to potassium deficiency, affected plants have very dark green foliage in early summer, later the leaves become purplish-bronze in colour, older leaves may become brittle and patches within the leaves may die and crack away. Severe potassium deficiency in sugar beet and mangolds may also result in death of parts of the leaves between the veins. Legumes are particularly sensitive to shortages of potassium, a moderate deficiency may result simply in poor growth but more acute deficiencies cause a pattern of yellow spots to appear, later the spots turn brown and the tissue involved dies. Both tree fruit and soft fruit are quickly affected by potassium deficiency; the effects often seen on gooseberries and currants grown on potassium-deficient soils

TABLE 10

APPROXIMATE DRESSINGS OF FERTILISERS TO GIVE MOST PROFIT FOR AVERAGE CONDITIONS AT 1957 PRICES

	Dressings of plant foods			Approximate equivalent dressings of fertilisers			Appropriate plant food ratio of compound fertiliser
	N	P_2O_5	K_2O	Ammonium sulphate (20 % N)	Superphosphate (18 % P_2O_5)	Muriate of potash (50 % K_2O)	N : P_2O_5 : K_2O
	cwt. per acre of plant food			cwt./acre of fertiliser			
CEREALS*							
Winter wheat							
Responsive varieties†	0·7	0·4	0·3	3½	2	½	1 : ½ : ½
Other varieties	0·5	0·4	0·3	2½	2	½	1 : ¾ : ½
Spring wheat	0·5	0·4	0·3	2½	2	½	1 : ¾ : ½
Barley							
Responsive varieties‡	0·7	0·4	0·3	3½	2	½	1 : ½ : ½
Other varieties	0·5	0·4	0·3	2½	2	½	1 : ¾ : ¾
Oats	0·3	0·4	0·3	1½	2	½	1 : 1¼ : 1
POTATOES	1·0	1·0	1·5	5	5	3	1 : 1 : 1½
SUGAR BEET							
Ordinary soils	1·0	0·5	1·5	5	3	3	1 : ½ : 1½
Soils low in phosphate	1·0	1·0	1·5	5	5	3	1 : 1 : 1½
KALE	1·0	1·0	1·0	5	5	2	1 : 1 : 1
MANGOLDS	1·0	1·0	1·5	5	5	3	1 : 1 : 1½
SWEDES	0·8	1·6	1·2	4	8	2½	1 : 2 : 1½

* For winter cereals most or all of the nitrogen needed should be applied as a top-dressing in spring. Where heavy dressings of nitrogen are to be used for spring cereals it may not be safe, or possible, to apply the full dressing by combine-drill, part of the nitrogen plus all the phosphate and potash should be combine-drilled, the remainder of the nitrogen being broadcast on the seedbed.

† Very responsive varieties of wheat include Hybrid 46, Capelle, Nord Desprez, Bersee and Atle.

‡ Very responsive varieties of barley include Kenia, Proctor, Herta, Freja.

are a hardening and browning of the leaves associated with a "scorch" affecting the leaf margins.

Trace element deficiencies arising from shortages of manganese, copper, zinc, boron, iron or molybdenum may also give rise to symptoms but a satisfactory diagnosis is usually a matter for a skilled Advisory Officer who should be consulted whenever crops show leaf discoloration or death of tissue which cannot be easily explained.

MOST PROFITABLE FERTILISER DRESSINGS

Deficiency symptoms call attention to very serious shortages of N, P and K which must be rectified at first opportunity; more normal crops generally give profitable responses to fertiliser dressings without there being any symptoms present on unmanured plants. Recommendations for manurial dressings in "normal" cropping have been made by averaging the results of field experiments carried out over many years and on a wide variety of soils in which the *extra* yields given by fertilisers have been measured. From these figures, knowing crop and fertiliser prices, it is possible to work out the "optimum" dressings of fertilisers which return maximum profit. Some recommendations for common arable crops taking the country as a whole are given in Table 10.

Recommendations made in Table 10 are for average conditions in England, they should be modified to allow for: (1) climate, (2) soil type, (3) level of fertility, (4) use of farmyard manure, and (5) past cropping on particular fields. The following principles may serve as a guide:

ADJUSTMENTS TO STANDARD MANURING GIVEN IN TABLE 10

	N	P_2O_5	K_2O
		cwt./acre of plant food	
Wet areas ...	deduct 0·4	add 0·2	—
Dry areas ...	add 0·2	deduct 0·2	—
Use of farmyard manure ...	—	deduct 0·4	deduct 0·4
Very poor soils	—	add 0·2	add 0·2
Richer soils ...	—	deduct 0·2	deduct 0·2
Continuous arable cropping ...	add 0·2	—	add 0·2

	ammonium sulphate	18% super-phosphate	50% muriate of potash
		cwt./acre of fertiliser	
Wet areas ...	−2	+1	—
Dry areas ...	+1	−1	—
Use of farmyard manure ...	—	−2	−1
Very poor soils	—	+1	$+\frac{1}{2}$
Richer soils ...	—	−1	$-\frac{1}{2}$
Continuous arable cropping ...	+1	—	$+\frac{1}{2}$

By taking standard recommendations (Table 10) as a basis, and by allowing for other local factors in this way, manuring on a particular farm may be matched up to soils and cropping systems in such a way that the land is neither excessively depleted nor built up in plant nutrients. The effects of levels of fertility and soil type are best assessed by an Advisory Officer with the aid of recent analyses of the soils concerned.

AGRICULTURAL SALT AS A FERTILISER

Agricultural salt is a valuable fertiliser for sugar beet and mangolds for the sodium which it supplies is essential if full crops are to be grown. Dressings of 3 to 5 cwt. of salt per acre given to beet produce 3 to 4 cwt. extra sugar per acre. Although salt reduces the need of these two crops for potash, some potash should be supplied when salt is used or soil potassium reserves may be depleted seriously. Sodium is also supplied by nitrate of soda and, to some extent, by kainit and low-grade potash salts so there is no need to apply agricultural salt if these fertilisers are given. There is no sure evidence that salt is of benefit to any other agricultural crops.

METHODS AND TIMES OF APPLYING FERTILISERS

The value of a fertiliser dressing is affected by the way it is applied. *Nitrogen* is mobile in soil moisture, nitrogen fertiliser dressings applied on the surface are washed down to the roots by rain but any excess of nitrogen not used by the crop is lost by leaching before another crop is grown. *Phosphate* and *potash* combine with the soil, they are not mobile in soil

moisture and are not easily lost by leaching *but* since they cannot move to the roots, top-dressings are of little immediate value. Therefore all phosphate and potash dressings must be applied in such a way that they are in close proximity to the roots which develop soon after germination or planting.

CEREALS

It is doubtful whether there is any worthwhile benefit from nitrogen given to *winter cereals* at sowing as compared with applying all the nitrogen in spring. On poor soils it may be justified to apply not more than 1 cwt. per acre of sulphate of ammonia or its equivalent in compound fertiliser at sowing. The rest of the nitrogen for winter wheat should be given as a top-dressing in spring. Where heavy dressings are used half may be given in March and half early in May.

For *spring cereals* all the nitrogen should be given at sowing time or shortly afterwards. Late top-dressings in May increase the risk of lodging and may increase the percentage of nitrogen in the grain thus reducing malting quality. Combine-drilling sulphate of ammonia for spring cereals produces slightly higher yields of grain than broadcasting the same quantity. Therefore for spring wheat, barley, and oats it is best to *combine-drill* a compound fertiliser to supply all the phosphate and potash together with part or all of the nitrogen, extra nitrogen needed to make up the quantity recommended in Table 10 being broadcast soon after sowing.

All phosphate and potash needed by both winter and spring cereals must be applied by combine-drill if maximum value is to be obtained from the fertiliser. Generally combine-drilled phosphate and potash is twice as efficient as comparable broadcast dressings (the amounts of phosphate and potash recommended in Table 10 for cereals are intended to be applied in this way).

POTATOES

Potatoes should have the whole fertiliser dressing applied immediately before planting in such a way that it is placed near the seed. When planting by hand in furrows of ridged land, this may be achieved by broadcasting fertiliser over the furrows before planting. When planting by a machine working on flat land the planter should be fitted with a

fertiliser attachment to place the dressing about 2 in. to the side of the seed and a little deeper.

SUGAR BEET AND MANGOLDS

Both crops should receive all the fertiliser needed before drilling, broadcasting and harrowing in the dressing of NPK fertiliser just before final seedbed preparations is satisfactory. Agricultural salt may cause capping on heavy soils and it should be spread and ploughed in in winter or else spread after ploughing but a few weeks before sowing.

SWEDES AND KALE

Swedes should receive all the necessary fertiliser before sowing. Broadcasting and harrowing into the seedbed is satisfactory for crops grown on the flat. Where swedes are sown on ridges shallow furrows should be opened, the fertiliser is then distributed along the furrows which are closed to make the final ridges for sowing. Fertilisers for **kale** should be worked into the seedbed before sowing. In wet areas and on light soils it may pay to give some nitrogen in the seedbed and follow with a top-dressing of 3 cwt. per acre of "Nitro-Chalk" in July.

PEAS AND BEANS

These crops generally require no more than 2 cwt. per acre of ordinary strength superphosphate and 1 cwt. per acre of muriate of potash or the equivalent as a compound fertiliser. To obtain a profitable response from this dressing it must be placed near to the seed by a sideband placement drill. Bands of fertiliser placed 2 in. to the side of the seed and 1 in. deeper are safe, combine-drilling with the seed may be dangerous in dry weather and on light soils. Where sideband placement cannot be used and fertilisers are to be broadcast, phosphate and potash should only be applied for peas and beans where analyses show the soil to be deficient in these nutrients, on richer soils a profitable return may not be obtained from broadcast dressings.

Horticultural crops grown on *ordinary soils* also benefit from sideband placement. Dressings placed 2 in. to the side

of the seed and 1 in. deeper will often given higher yields of earlier produce than equivalent broadcast dressings.

FERTILISERS FOR GRASSLAND

It is not possible to make general recommendations for manuring grassland in the way one recommends dressings for arable crops since the amounts of fertiliser needed and justified for grass depend very much on type of soil, type of herbage, district and, *above all*, on methods of management and utilisation of the grass.

Fertiliser nitrogen is necessary to promote extra growth at the beginning and end of the season and to give heavy cuts of grass for silage, hay, or drying. There may be little justification for fertiliser nitrogen when herbage contains adequate and vigorous clover and the grass is being used only for summer grazing.

Phosphate and potash manuring of established grass depends mainly on the system of utilisation. Both nutrients may need to be applied for reseeding, for improving permanent pasture, and particularly for promoting the growth of legumes in the herbage. Where frequent heavy cuts of grass for hay and silage are taken, or where milk cattle are grazing intensively, there is a serious drain on soil potassium reserves, one or more dressings of muriate of potash may be needed each season, and a light dressing of basic slag or superphosphate should be given each winter. Where grassland in good condition is being grazed by sheep, by beef cattle, or by stores, most of the plant nutrients in the herbage eaten are returned to the soil in excreta and there is little loss of phosphorus and potassium from the field; occasional light dressings of phosphate and potash fertilisers will keep such grassland in good condition. If analyses show the soil to be seriously deficient in phosphorus or potassium extra fertiliser dressings are needed before any improvement in grassland can be expected.

FERTILISER DRESSINGS ON SMALL AREAS

Recommendations for fertiliser dressings stated in cwt. per acre are often not appropriate for use on small-holdings, market gardens or glasshouses. Approximate conversions

into pounds per rod and ounces per sq. yard are given in Table 11.

TABLE 11

CONVERSION TABLE FOR RATES OF APPLICATION

Per acre	Per rod	Per sq. yd.
1 cwt.	11 oz.	½ oz.
2 cwt.	22 oz.	¾ oz.
3 cwt.	2 lb.	1 oz.
4 cwt.	2¾ lb.	1½ oz.
5 cwt.	3½ lb.	2 oz.
8 cwt.	5¾ lb.	3 oz.
10 cwt.	7 lb.	3¾ oz.

FERTILISER PRICES AND VALUES

There is now no control of fertiliser prices. Subsidies are paid on inorganic nitrogen and phosphate contained in both straight and compound fertilisers. There is no subsidy on potash. Both prices and subsidy rates have increased in recent years, Table 12 gives quotations for prices and the subsidies current in May, 1957. Subsidies on other inorganic nitrogen and inorganic phosphate fertilisers, and on compounds, are paid according to the amounts of N and of soluble and insoluble phosphate which they contain. There is no subsidy on organic fertilisers either sold as straights or in compounds.

UNIT PRICES

To compare fertiliser values " unit prices " are calculated to give the cost of 1 per cent. of N, 1 per cent. of P_2O_5 or 1 per cent. of K_2O. The price per ton of straight fertiliser *in shillings* divided by the percentage of the nutrient which it contains gives a unit value for N, P_2O_5 or K_2O. Values calculated from 1957 prices are stated in Table 12. Unit cost of N as nitrate is higher than the cost of N as ammonium. Water-soluble P_2O_5 costs more per unit than insoluble P_2O_5 in basic slag, which, in turn, is more expensive than insoluble P_2O_5 in ground rock phosphate. Unit cost of nitrogen in organic materials is considerably higher than unit cost of straight inorganic nitrogen. A unit of potash in sulphate of potash is more expensive than a unit supplied by the muriate.

TABLE 12

PRICES* OF STRAIGHT FERTILISERS, SUBSIDIES AND UNIT VALUES IN MAY, 1957

Fertiliser	Price per ton £ s.	Analysis %	Price per unit (shillings)	Subsidy per ton £ s. d.
		Nitrogen (N)		
Sulphate of ammonia	21 2	20·8	20·29	6 15 0
"Nitro-Chalk"	18 4	15·5	23·48	5 0 0
Nitrate of soda	28 0	16·0	35·00	5 4 0
		Soluble P_2O_5		
Triple superphosphate	40 0	47	17·02	17 12 6
Superphosphate	14 16	18	16·44	6 15 0
		Insoluble P_2O_5		
Basic slag	7 5	15	9·67	3 6 0
Basic slag	12 15	22	11·59	4 15 6
Ground rock phosphate	12 9½	29	8·60	5 16 0
		Potash (K_2O)		
Muriate of potash...	17 10	50	7·00	nil
Muriate of potash...	20 9	60	6·82	nil
Sulphate of potash	22 11	48	9·40	nil

* These prices are for 6-ton lots delivered to the nearest station except for muriate of potash and sulphate of potash where prices are quoted at the port and delivery to the farmer's station is an extra charge.

All these facts should be taken into account in using unit values to assess the real worth of a compound fertiliser.

The prices for fertilisers usually quoted are for 6 ton lots delivered in the February–June period to the farmer's nearest station, smaller lots are charged at higher rates per ton. In addition the manufacturers usually offer an early delivery rebate on compound fertilisers and on sulphate of ammonia delivered in late summer, autumn and early winter. Rebates for early delivery are highest in late summer and least in January; they are designed to ease the manufacturers' storage and transport problems, farmers who use appreciable amounts of fertilisers and have adequate storage can save a considerable sum by early buying. Modern granulated fertilisers packed in paper sacks store well if simple precautions are taken. The sacks should be handled carefully and should be undamaged when put into store, piles of sacks (which should not be too high) should be raised off a concrete or earth floor on a wooden framework and they should be protected from rain.

RESIDUAL VALUES OF FERTILISERS

Compensation is payable to an outgoing tenant for the residual fertility remaining from fertilisers which he used during the last years of his tenancy. Amended values for compensation came into force on 25th March, 1953. Where no crop has been taken since the application, the value is the reasonable cost of the manure (including delivery and spreading). After one or more crops the values change as shown in Table 13; this Table also gives the current " unit values " which are normally used to calculate the value to a tenant of previous fertiliser dressings.

LIMING

Soils which have no natural reserve of free calcium carbonate (limestone or chalk) lose lime continuously by the leaching action of rainwater. This loss is intensified by the use of fertilisers which acidify the soil, principally ammonium sulphate and compounds containing this material. Rain removes lime equivalent to about 3 cwt. per acre of carbonate of lime each year from arable land in low-rainfall areas. In wet areas the loss is greater. A dressing of 1 cwt. per acre of sulphate of ammonia causes the loss of at least

TENANT'S COMPENSATION FOR RESIDUAL VALUES OF FERTILISERS

	Fractions of value remaining			
	After one crop	After two crops	After three crops	After four crops
Nitrogen				
Inorganic N*	nil	nil	nil	nil
N in dried blood	nil	nil	nil	nil
Organic N, other than dried blood	one-half	one-quarter	nil	nil
Phosphoric acid				
Soluble	two-thirds	one-third	one-sixth	nil
Insoluble	one-third	one-sixth	one-twelfth	nil
Total in bone products	one-half	one-quarter	one-eighth	nil
Total in other materials	one-third	one-quarter	one-twelfth	nil
Potash				
Total K_2O	one-half	one-quarter	nil	nil

* By inorganic N, fertilisers like sulphate of ammonia, "Nitro-Chalk," nitrate of soda, etc., are implied.

UNIT VALUE OF 1 PER CENT. OF A TON OF FERTILISER

		Inorganic fertilisers		
Phosphoric acid	s. d.	s. d.	s. d.	
Soluble P_2O_5	6 8	3 4	1 8	nil
Insoluble P_2O_5	3 4	1 8	10	nil
Total P_2O_5 in other materials	3 4	1 8	10	nil
Potash				
Total K_2O	3 6	1 9	nil	nil
		Organic fertilisers		
Nitrogen	s. d.	s. d.	s. d.	
Organic N (other than dried blood)	7 0	3 6	nil	nil
Phosphoric acid				
Total P_2O_5 in bone products	5 0	2 6	1 3	nil
Total P_2O_5 in other materials	3 4	1 8	10	nil

For liming or chalking of land the value is the reasonable cost of the lime or chalk as applied to the land (including the cost of delivery and application) reduced by one-eighth part of the amount thereof for each growing season since application.

For basic slag the amount may not exceed two-thirds of the reasonable cost, including delivery and spreading, after one crop; one-third after two crops and one-sixth after three crops.

For purchased farmyard manure, two-fifths of the reasonable cost after one crop, nil after more than one crop.

For shoddy and similar organic manures there are special allowances additional to the figure obtained from the table above.

For bracken, moss litter, peat and bean straw, etc., the value is 12s. per ton where no crop is taken, 6s. after one crop.

1 cwt. per acre of carbonate of lime in addition to the ordinary loss caused by rainfall. The maintenance of a satisfactory lime status by means of regular dressings is a basic principle of good farming on all soils having no natural reserve of lime. Even in areas of low rainfall, dressings of lime supplying 30 cwt. per acre of burnt lime (CaO) or 50 cwt. per acre of ground limestone ($CaCO_3$) are likely to be needed once every 5 years to correct the loss of lime which occurs in intensive arable farming.

Often the first signs of acidity developing are bare patches or poor growth of acid-sensitive crops like sugar beet or barley, other indications are the presence of certain weeds such as sorrel and spurrey. When acidity is suspected a soil test should be carried out by the Advisory Service, the results of the test will be used to provide a recommendation for liming the soil approximately to the neutral state (pH 7). After correcting initial acidity rotational dressings of lime should be given to maintain a satisfactory status. Indiscriminate and excessive liming without proper advice should be avoided since, besides being wasteful, there are a few soils, such as fen peats, where excess lime induces trace element deficiencies.

SUBSIDY ON LIME

There is a subsidy of 60 per cent. of the cost of liming materials plus a contribution to the cost of spreading. (The rate of contribution is at present increased during the summer months.) Application forms for subsidy payments are provided by the supplier.

FORMS OF LIMING MATERIALS

The value of a liming material can be expressed as the amount of acid neutralised and for this purpose all recognised sources of lime are equally suitable. Ground carbonate of lime ($CaCO_3$) is just as effective as chemically equivalent amounts of burnt lime (CaO) or slaked lime ($Ca(OH)_2$); generally there is no advantage from using these latter materials which are more expensive. Burnt limes contain about 80–95 per cent. of CaO, and ground limestones 45–52 per cent. of CaO. One ton of burnt lime is approximately equivalent to $1\frac{1}{3}$ tons of slaked lime and to 2 tons of

ground limestone. Besides being cheaper per unit of lime, ground limestones are more convenient and pleasant to handle and spread than burnt or slaked lime; limestone also stores indefinitely while burnt lime may absorb moisture causing burst bags which set.

The Fertilisers and Feeding Stuffs Regulations (1955) require that the amount of lime (CaO) in ground limestone should be stated and also that the percentage of material which will pass through a 100 mesh B.S. sieve should be declared. Generally commercial ground limestones are ground so that 60 per cent. goes through the sieve. Such a material will act sufficiently quickly and be as generally satisfactory as burnt lime. It is important that when harder limestones are used there should not be a high proportion of very coarse particles, generally ground limestones are satisfactory if all the material passes the 10 mesh screen. *Ground chalk* is very similar to ground limestone. *Limestone dust* is a by-product lime, usually all passes the $\frac{1}{8}$ in. screen and 25 per cent. passes the 100 mesh sieve; being coarser than ground limestone it should be applied at higher rates. *Small chalk* and *screened chalk* are important liming materials in some areas. Small chalk is in lumps from 2 in. diameter down to dust, screened chalk is usually from $\frac{1}{2}$ in. to $\frac{1}{4}$ in. particles down to dust in size. As chalk is a soft rock which weathers quickly in the soil these coarse grades are satisfactory for liming, corresponding coarse batches of a hard limestone would be of little use. *Mixed limes* and *magnesium limes* may be valued on their declared " neutralising values," magnesium limes may be particularly useful in areas where magnesium deficiency is suspected. *Natural liming materials* used in areas where they are available are lump chalk, marl and calcareous sea sands. *Waste carbonates of lime* are produced by beet sugar factories, by paper works and by water works; they should be judged on their lime content or neutralising value, also on the amount of water they contain and the ease of spreading them.

ARABLE CROPS

ROTATION OF CROPS

CROPS should not be regarded as separate entities, but as part of a system or rotation designed to utilise soil and climate potentialities to best advantage. In this way, economies in labour, cultivation and manuring can be

TABLE 14: TYPICAL MODERN ROTATIONS

1. *Mainly Arable Systems:—*

Potatoes	Potatoes	Sugar Beet
Wheat	Wheat	Barley
Sugar Beet	Sugar Beet	Seeds
Spring Cereal	Peas	Potatoes
	Cereal	Wheat

2. *Arable Systems with Livestock:—*

Roots (Sugar Beet, Swedes, etc.)	1–3 year Ley
Barley	Spring Wheat
Seeds (1–2 years)	Barley
Oats	Kale
Potatoes	Barley or Spring Wheat
Wheat	

3. *Mixed Farming Systems:—*

Light and medium soils		*Heavy soils*
3-year Ley	4-year Ley	4-year Ley
Wheat	Wheat	Wheat
Oats	Arable Silage	Oats and Beans
Roots (Kale, Mangolds, Sugar Beet)	Wheat	Roots (Kale, Mangolds)
Oats or Barley	Oats	Oats

4. *Dairy and Livestock Systems:—*

3–4-year Ley	4-year Ley
Kale	Oats
Oats or Dredge Corn	Roots (Kale, Swedes, etc.)
	Oats

effected and a measure of control exerted over weeds, pests and diseases. Crops must be selected with a view to suitability of soil, cash returns, labour distribution, opportunity for cleaning the land and spreading the financial risks. The Norfolk Four-Course System, for generations the most widely-practised rotation in this country, is the basis for many modern crop rotations.

In recent years the long ley has come to be regarded as the pivot of the rotation rather than the root crop and increasingly greater emphasis has been placed upon it. After a period of recuperation under ley, arable cropping can be carried out economically as regards manuring and weed control. This alternation of ley with arable has for long been known in the north of Britain as "Alternate Husbandry." More latterly the term Ley Farming has been adopted. The system requires adequate fencing and water supplies in all fields and reasonably ploughable land and for these reasons cannot be carried out indiscriminately all over the country.

CATCH CROPPING

Consists of snatching an extra crop between two of the main crops of the rotation without interfering with the normal system of farming. For instance, Italian ryegrass undersown in, say, wheat can be grazed after harvest and throughout the autumn and winter until ploughed up the following spring prior to sowing a spring cereal such as oats or barley. Another example is the sowing of turnips or crimson clover on a disced corn stubble in the autumn immediately after harvest. Such a crop provides early spring keep for sheep before it is ploughed up for mangolds or quick-growing turnips. Mustard is sometimes sown on fallow land for ploughing in, whilst Italian ryegrass sown after early potatoes are lifted is often ploughed down in the autumn for green manure.

CROPPING POLICY

The aim in cropping should be to secure the maximum profitable yield with the least exhaustion of the land whilst maintaining it as clean and free from disease and insect pests as possible. In the following pages the recommendations for

individual crops are given in the light of experience on many soils over many years and must be modified to suit local conditions. In particular, the fertilising recommended should be regarded as normal and should be compared with the "optimum" dressings given in Table 10.

ROOTS

TURNIPS AND SWEDES

Require similar treatment and thrive best in a cool, moist climate on lighter to medium types of soil. In hot dry weather the "fly" and mildew are troublesome.

Varieties:—

White turnips: 8 per cent. dry matter:	Lincolnshire Red, Greystone, Pomeranian White.
Soft Yellow turnips: 9 per cent. dry matter:	Fosterton Hybrid, Early Sheep Fold.
Hardy Yellow turnips: 10 per cent. dry matter:	These are hardy and frost resistant and closely resemble swedes. Aberdeen Yellow in both green top and purple top strains. The Bruce (purple top), the Wallace (green top), show resistance to "finger and toe" disease.

Swedes are usually classed as purple, bronze or green tops.

Purple Skin: 11 per cent. dry matter:	Eclipse, Magnificent, Majestic, Purdy's Purple Top, Tipperary, Magnum Bonum.
Bronze Skin: 12 per cent. dry matter:	An intermediate type. Mancunian, Lord Derby, White-fleshed.
Green Skin: 13 per cent. dry matter:	Keepwell, Wilhelmsburger.

CLASSIFICATION OF TURNIP AND SWEDE VARIETIES

Variety	Average per cent. dry matter	Order of Merit: Keeping quality	Order of Merit: Yield of dry matter
Soft White turnips ...	$7\frac{1}{2}$–8	6	6
Soft Yellow turnips ...	$8\frac{1}{2}$–9	5	5
Hardy Yellow turnips ...	10	4	4
Purple Skinned swedes	11	3	1
Bronze Skinned swedes	12	2	2
Green Skinned swedes ...	13	1	3

Cultivations—Autumn cleaning of the stubble is advisable, followed usually by the application of dung unless applied in the rows in the spring as in the wetter districts. Crops should be grown on ridges in wetter districts and on the flat in dry areas.

Seeding—Turnips, 3 lb. per acre; swedes 4 lb. per acre. 1 lb. of seed is ample under good conditions. Swedes are sown from the middle of May to middle of June. Turnips in June. Best width of drill is 27 in. on ridge or 20–24 in. on the flat.

Singling—Single as soon as first rough leaves are formed to 10 in. in the row, and inter-row hoe as frequently as necessary.

Manuring—Lime is essential. Where regular liming is needed the root break is a convenient point in the rotation to make good this deficiency.

Farmyard manure ...	15 tons per acre applied in autumn or spring.
Sulphate of ammonia...	1 cwt. per acre when dung not available.
Superphosphate ...	4 cwt. per acre.
Muriate of potash ...	1 cwt. per acre.

Harvesting—White turnips are ready in September and the soft and hardy Yellows follow in sequence with the swedes coming last about November.

Roots must be protected from frost either by ploughing in or lifting and clamping. Topping and tailing should not be drastic or keeping quality will be impaired.

Average yield per acre—White turnips: 12–14 tons; yellow turnips: 14–16 tons; swedes: 15–20 tons.

MANGOLDS

Suited to dry sunny districts and deep rich loam soils. Varieties classified according to shape: globes, tankards, intermediate and long. Colour differences exist within each group. The dry matter content—and hence the feeding value—shows marked variation between varieties and selection should be made on this basis. In trials carried out by the National Institute of Agricultural Botany, the variation in dry matter content was of the order 15·1 to 7·3 per cent.

Cultivations—The crop may be grown on the ridge or the flat. It prefers a fine, firm, stale seed bed. Dung is best applied in the autumn and ploughed in.

Seeding—6–10 lb. per acre in rows 26–28 in. on the ridge and 20–22 in. on the flat. It is an advantage to soak the seed for 24 hours before sowing. Time of seeding varies from mid-April in the Midlands to mid-May in the south. Gaps in a field may be filled by transplanting.

Singling to 10 in. should take place as soon as the first rough leaves are formed—usually about six weeks after drilling.

Manuring—In addition to say 12–14 tons per acre farmyard manure, the following mixture is suggested:—

Sulphate of ammonia	3–4 cwt. per acre.
Superphosphate	2–3 ,, ,,
Muriate of potash	1 ,, ,,
Common salt	3–4 ,, ,,

The salt should not be mixed with the other fertilisers but applied separately 3–4 weeks before drilling. After singling, 1–2 cwt. per acre nitrate of soda can be applied to advantage.

Harvesting—Mangolds must be lifted and safely stored before frost is imminent. The tops are screwed off by hand, the roots are not trimmed. Mangolds may be clamped with the tops left on provided this is done when they are dry.

Yield—20–50 tons per acre. Mangolds should not be fed until after Christmas or they may give rise to scouring in stock.

FODDER BEET

Fodder beet is a recent introduction into British Agriculture, being the product of crosses between sugar beet and

mangolds and of selections from high-yielding sugar beet types. On the Continent, whence most of the strains used in this country derive, the term "fodder beet" is used to cover all types of Beta spp. used for fodder.

The classification of strains at present adopted in this country follows the Danish system and uses the percentage of dry matter in the root as its basis:—

Over 20 per cent. D.M. ...	Sugar beet type, e.g., Hunsballe, Pajbjerg.
14–19 per cent. D.M. ...	Intermediate type, e.g., Red Øtofte, Yellow Daeno, Barres Øtofte.
Below 14 per cent. D.M. ...	Mangolds.

Compared with mangolds, fodder beet normally gives a higher yield of dry matter per acre; this results from the higher dry-matter content of the roots and a much larger yield of tops. On the other hand it is more difficult to lift, clean and top.

Except for harvesting, the cultivation of the crop follows the same lines as for mangolds.

Root yields for the higher dry-matter types average about 18 tons per acre; the yield of tops varies considerably, but averages about 10 tons per acre.

In this country, fodder beet is utilised to a large extent in pig feeding; it can also be fed to cattle and horses.

SUGAR BEET

Can be cultivated successfully on many soils, especially sandy soils, loams, silts and peat. Heavy soils in wet districts are not suitable, but beet can be grown on heavy loams if care is taken to lift and cart off early in autumn. Deep, friable soils with ample rainfall during the growing season and a dry autumn to complete maturity and allow easy carting off, constitute ideal conditions.

Strains—Strains are frequently described as E or N according to the sugar content, the N strains having the higher percentage of sugar. The average differences in sugar content between strains, however, are rarely greater than 1 per cent. Much greater differences are shown from year to year and from field to field.

Battle's E—High yield roots, relatively low sugar content, medium-sized tops, resistant to bolting, average yield of sugar per acre.

Bush E—Average yield roots and sugar, large tops, resistant to bolting even with early sowing.

Garton's C—Average yield roots, relatively low sugar content, large tops, moderate bolting. Not suitable for black fen soils.

Goldsmith's Dobrovice—Moderate yield roots and sugar, large tops, incidence of bolting rather high.

Hilleshog N—High sugar content, small tops, yield of sugar above average. Bolting rather high.

Johnson's E—Average yield roots and yield of sugar rather above average. Low bolting strain, large tops.

Sharpe's Klein E—High yield of roots and sugar, medium tops, low bolting.

Webb's No. 2—Yield of sugar slightly above average, small tops, average bolting.

Other recent varieties which show promise are Battle's N, Bush N, Hilleshog E, Hilleshog Polyploid and Johnson's N. Breeders are trying to secure strains which give only one or two seedlings per cluster, for this would greatly facilitate singling. The question of non-bolting strains is also important, especially with the development of mechanical harvesting, as well as resistance to the virus causing the disease " yellows."

Quantities of Seed per Acre—18–20 lb. for March and early April sowings, 15 lb. for mid-April and 12 lb. for sowing late April and May. Rubbed seed 8–10 lb. per acre. Rubbed seed is natural seed pared down in special machinery to produce a higher proportion of seed pieces which will grow only one seedling, the main object being to facilitate singling.

Time of Sowing—Early sowing gives better yields: experiments have shown that a crop drilled in early April produces about 2 tons per acre more beet than when sown at the beginning of May. Beet may be sown from mid-March onwards if good seedbed conditions prevail and sowing should be completed in April except in late districts.

Average Yield per Acre—9–10 tons. Good crops up to 18 tons. The average sugar content is about 15½ per cent.

and the basal price per ton of washed beet paid by the factories is for roots of this sugar content: a higher rate is paid for roots richer in sugar content than 15½ per cent., and deductions are made if the sugar content falls below this figure.

Cultivations—Sugar beet usually follows a cereal in the rotation: the roots penetrate deeply and subsoiling may be necessary if there is a pan. Normally, ploughing 10 in. to 12 in. deep provides the tilth for the production of shapely and easily harvested roots. One-way ploughing is better than ridge and furrow work as it keeps the surface of the land level for ease and efficiency of the subsequent inter-row cultivations. Ploughing should be completed before Christmas, especially on soils where it is difficult to obtain a fine seedbed without plenty of frost action.

Manuring—Soil reaction should be as near pH 6·5 as possible: if the soil is acid apply lime to lime requirement but not in excess as symptoms of manganese and boron deficiency may develop if the soil is very alkaline.

Farmyard manure is very valuable and even a small dressing of 6–10 tons per acre will increase the yield by 2 tons per acre, even with a large balanced dressing of fertilisers. For average loam soil in addition to dung apply:—

	cwt. per acre
Sulphate of ammonia	4
Superphosphate	2
Muriate of potash	1
Salt	4

Salt is a plant food for beet and invariably increases yield even in the presence of potash. It should be ploughed in during the winter or broadcast in the spring at least three weeks before sowing. The remainder of the fertilisers should be applied to the seedbed: trials have shown that there is nothing to be gained by top-dressing except on light soils or on unthrifty crops or where the field is very weedy, in which case the application of all the nitrogen before drilling may stimulate weed growth and make singling difficult: top dressing should not be done later than singling, otherwise the sugar content may be reduced.

The Seedbed—The sugar beet " seed " is really a fruit containing up to four true seeds; thus, although the clusters

are relatively large, the true seeds are very small and have only a small reserve of plant food. The seedbed must, therefore, be fine and moist to allow the seed to establish itself quickly and firm, in order that the seed shall be in close contact with the soil and will not dry out during germination. The aim should be a fine layer of soil about 1 in. deep overlying a well worked but firm tilth upon which the seed can be deposited. It is important that the seed should be compressed into this firm layer of soil, either by rolling after drilling or by fitting single wheel rollers to the drill set to run behind the drill coulters.

Plant Population—In the cultivation of the crop, the continuous line of seedlings is thinned out as for mangolds, and the number of plants left to grow on and produce the crop is a most important factor in determining the yield of roots. At least 25,000–30,000 plants per acre should be left, the higher figure for all except the most fertile soils where slightly fewer plants will often be successful. Table 15 gives the theoretical plant population at different row widths and singling distances. This gives the *maximum* possible plant and takes no account of subsequent losses during horse-hoeing or from the depredation of rabbits or destruction by insect pests.

Although a plant population of 30,000 can be theoretically obtained equally well by singling 24 in. rows at 8 in. spacing, the leaving of so many plants in the row is difficult to achieve in practice, and a rather wider singling distance combined with 18–21 in. rows is best. 15 in. rows have been shown to produce the highest yields, but the increases gained by narrowing the row width to this extent are not sufficient to compensate for the extra difficulty in cultivation. Wider rows than 21 in. are only justified on foul land.

Beet seedlings are very sensitive to weed competition and the first hoeing, cutting as close to the rows as possible, should be done as soon as the rows are visible across the field. Usually, two hoeings are necessary before singling, and three or four afterwards until the development of the roots and foliage makes further operations impossible without causing damage. The equipment used for the row crop cultivations must be the same width as the drill to avoid cutting up plants along the joins of the drilled rows: horse-drawn implements or toolbars mounted on tractors may be used.

TABLE 15: ROW WIDTH

Singling Distance	15	16	17	18	19	20	21	22	23	24
8	52,300	49,000	46,100	43,600	41,300	39,200	37,300	35,600	34,100	32,700
9	46,500	43,600	41,000	38,700	36,700	34,800	33,200	31,700	31,300	29,000
10	41,800	39,200	36,900	34,800	33,000	31,400	29,900	28,500	27,300	26,100
11	38,000	35,600	33,500	31,700	30,000	28,500	27,200	25,900	24,800	23,800
12	34,800	32,700	30,700	29,000	27,500	26,100	24,900	23,800	22,700	21,800
13	32,200	30,200	28,400	26,800	25,400	24,100	23,000	21,900	21,000	20,100
14	29,900	28,000	26,400	24,900	23,600	22,400	21,300	20,400	19,500	18,700

The ideal outfit must not only allow lateral movement for accurate steering but should have independently mounted and sprung hoe blades so that the same depth of working is maintained regardless of irregularities in the ground level. The first cultivation should be deep and close to the rows, the later ones using A hoes working shallowly in between the rows.

Singling—The ideal stage is when most of the plants bear four leaves. Singling later than this causes serious reductions in yield and the longer the delay the greater the loss. Singling is normally piecework and the most satisfactory basis of payment is per 100 yard run of row, which automatically allows for differences in row width. Singling may be performed in one operation by long-handled hoe or, as in some districts, notably the Fens, the crop is first bunched by a long hoe and then singled by hand. A few doubles left after singling do not decrease the yield but cause extra work at harvest and hinder mechanical harvesting and should be singled at the second hand-hoeing which is carried out about a month after singling.

Beet crops may be bunched mechanically by hoeing across the rows or by " down the row " thinning machines which travel along the row. Only very regular stands of seedlings can be treated in this way or a loss of plant population results. The effects of bunching mechanically are to make singling quicker and to allow a delay of about a week in singling without loss in yield.

Harvesting—Harvesting is determined by the contract with the British Sugar Corporation and this entails a continuous supply of beet to the factory from the last week in September until the factory closes at the end of the year. Over this period, yield and sugar content alter and although the weather, particularly the rainfall, may cause a different pattern of crop development in some years, as a rule similar variations are noted. Towards the end of September the crop increases in weight at about half a ton per acre per week. This falls off in October and November, but growth may still take place in December if the weather is open. Sugar percentage also increases during late September and early October and reaches its peak at the end of October; thereafter it falls.

Lifting—The roots are loosened by a horse or tractor drawn lifter, then pulled by hand, knocked to remove the soil and laid in rows ready for topping. The tops are severed from the roots with hand choppers.

A number of machines have now been developed for the mechanical harvesting of sugar beet. These equipments may either consist of a single machine which performs the complete operation of lifting, topping and knocking or two machines, one which tops the beet in the ground followed by another which lifts the topped beet and windrows them.

Protection of Beet from Frost—Frozen beet lose sugar rapidly; left growing in the field they are not affected except by very severe and prolonged frost, but once lifted the roots are susceptible. In frosty weather, small heaps of beet should be covered with tops, large roadside heaps with straw or hedge trimmings.

By-Products—In addition to the cash return from the sale of the roots, growers benefit from the by-products which form valuable food for stock.

Sugar Beet Tops—The tops, consisting of leaves and crowns of the roots, contain 15–17 per cent. of dry matter, which is rich in protein and sugar and can replace the usual root crops. Although analysis shows that 25 lb. beet tops have the same nutritive value as 40 lb. of mangolds, there is some waste, consequently equal quantities of tops and mangolds must be fed to obtain the same live weight increase. Keep the tops as clean as possible because sand is highly dangerous to the digestive system of the stock. The weight of tops per acre is, on the average, almost equal to the weight of washed beet delivered to the factory. When wilted the tops lose about a third of their weight. Fresh beet tops contain oxalic acid which causes scouring, but by allowing them to wilt for a week, the concentration of oxalic acid is greatly reduced: as an additional precaution about $\frac{1}{4}$ lb. precipitated chalk to every 250 lb. of tops should be fed.

Mature sheep eat 14–21 lb. of tops daily: as a rough guide, an acre of tops will feed 100 sheep for a week. A ewe flock will do well from October to January on beet tops with little more than a good supply of hay and a run out to grass until close to lambing.

A 10-cwt. bullock can consume 100 lb. of tops daily and, although cattle can rarely be finished on beet tops because

the supply runs out early in the New Year, tops can be used in the early stages of fattening and are especially valuable for feeding on the pastures when the cattle are waiting to go into winter fattening quarters. Care must be taken in feeding tops to dairy cows because of an impurity, betaine, which may taint the milk. No taints in milk should develop if the ration of tops does not exceed 40 lb. per day, fed, not in the cow house, but on pasture immediately after the morning milking. Surplus tops which cannot be fed fresh, can be conserved either by drying or ensilage. Drying tops is practised in Germany and efforts are now being made to develop the process in this country. The tops must be washed to free them from adherent dirt or collected in a very clean condition and the crowns must be shredded to permit drying at a temperature which does not char the leaves. Sugar beet top silage is best made in a pit and consolidation is necessary. No molasses are required, but it is important to have good drainage as beet tops are very wet and a large quantity of liquid is expressed during ensiling. The silage is palatable and up to 60 lb. per day can be fed to dairy cows: 7 lb. hay, 40 lb. sugar beet top silage and 4 lb. oats provide for the maintenance of a dairy cow and the first gallon of milk.

Sugar Beet Pulp—The residue from the sliced roots after the sugar has been extracted is dried and is sold back to the grower, either as beet pulp or with molasses added as molassed beet pulp. This dried pulp is a carbohydrate concentrate which experiments have shown to be equal in feeding value to oats. It may be fed as such to dairy cows or fattening cattle up to 4 or 5 lb. per day or it may be used to replace roots (4–6 lb. replacing 40 lb. of roots). The pulp should be soaked in half its own weight of water before feeding.

The factories have sufficient drying plant to dry all but a small proportion of the pulp they produce. The remainder is sold as wet pulp. Wet pulp is a valuable succulent food for all cattle and keeps well if clamped or ensiled, 1 lb. having a feeding value equivalent to 1½ lb. mangolds.

KOHL RABI

This crop is especially suitable for districts subject to drought and on stiff loam soils. May be used for folding or

feeding indoors. Not suited to cold wet soils. Highly resistant to "finger and toe" disease.

Varieties—Two varieties are commonly grown, one in which the leaves and bulbs are glaucous green, the other being reddish-purple. There is little to choose between them.

Cultivations—These follow the same lines as for mangolds though the crop is always grown on the flat in rows 20–24 in. apart. Seedlings may be transplanted.

Seeding—The seed is sown in April at 4 lb. per acre, and plants are later singled to 1 ft. in the rows.

Manuring—In addition to 15–20 tons dung per acre, the following mixture of fertilisers should be applied:—

	cwt. per acre
Sulphate of ammonia	3
Superphosphate	2–3
Muriate of potash	1

After singling the crop benefits from a top dressing of nitrate of soda at 1 cwt. per acre.

Harvesting—The roots stand frost and can be left growing until required, or they may be lifted and stored like swedes.

Yield—20 tons per acre.

CARROTS

Require a deep, sandy soil though they do well on peaty and fen soils.

Varieties—Red Altrincham is the heaviest cropping variety with good cooking quality. Stump-rooted varieties are best for shallow soils and the bunching trade, and Scarlet Intermediate for general purposes. White Belgian, because of its very high yielding propensities, is commonly grown for stock feeding.

Cultivations—The seed bed must be clean and very fine, firm and moist.

Seeding—The seed is drilled in rows 12–20 in. at 5–6 lb. per acre from mid-April onwards. A little barley or oats may be sown with the carrot seed to indicate the position of the rows and enable early inter-row cultivation to commence.

It may be mixed with sand to facilitate drilling. The seed may be soaked before sowing to encourage germination, and this may even have started.

Owing to the danger of carrot flies being attracted to the crop, thinning is not usually carried out since bruised plants by virtue of their pungent smell tend to attract the fly. Later in the season, rough thinning may be carried out to supply the bunch trade. Early in September slight earthing up may be carried out to cover the shoulder of the roots and prevent them greening.

Manuring—Dung is best applied to the previous crop or danger of fanged roots may arise. Liming, though not essential, is advisable in cases where an appreciable deficiency exists.

The following mixture of fertilisers is suitable for general purposes:—

	cwt. per acre
Sulphate of ammonia	2
Superphosphate	3
Sulphate of potash	1½–2

When the plants are 2–3 in. high it is advisable to top dress with nitrate of soda at 1 cwt. per acre.

Harvesting—The crop is usually ready from August onwards but the main crop is not lifted as a rule until October. The roots should be under cover before frost is likely, and can be clamped in a manner comparable to potatoes.

Yield—10–12 tons per acre. On ploughed-out grassland 20–25 tons per acre is not uncommon.

POTATOES

The crop can be grown satisfactorily on most types of free working soil, especially those rich in organic matter. The best cooking quality is secured when the crop is grown on the Old Red Sandstone and limestone soils. Being subject to frost damage, early potatoes can only be grown satisfactorily in coastal districts, such as the south-west of Scotland, Pembrokeshire and Cornwall.

Varieties—Varieties are classified as "first earlies," "second earlies," and "lates or main crops."

Varieties in common use are tabulated below:—

VARIETIES OF POTATOES

Name	Shape	Colour of flesh	Depth of eyes	Cropping capacity	Cooking quality
FIRST EARLIES:					
Arran Pilot*	Kidney	White	Shallow	V. Good	Fair
Home Guard*	Oval	White	Shallow	Good	F. Good
Ulster Chieftain*	Oval	White	Shallow	V. Good	Fair
Ulster Premier*	Kidney	White	Shallow	V. Good	Good
Ulster Prince*	Kidney	White	Shallow	V. Good	Good
SECOND EARLIES:					
Craig's Alliance*	Oval	White	Shallow	V. Good	V. Good
Craig's Royal*	Thick Kidney	Cream	Shallow	V. Good	V. Good
Ulster Dale*	Flat Kidney	White	Shallow	V. Good	F. Good
LATES OR MAIN CROPS:					
Arran Viking*	Oval	White	Medium	Excellent	Good
Kerr's Pink*	Round	White	Deep-pink skin	Excellent	Good
King Edward	Kidney	White	Shallow skin—splashed pink	Moderate	Excellent
Majestic*	Kidney	White	Shallow	V. Good	Good
Ulster Supreme*	Oval	White	Shallow	Excellent	Good

* Immune to wart disease.

Seed Certification—Maximum yield is dependent upon the use of healthy virus-free seed, and it is customary in districts where aphides are common to use new seed each year, or every other year. To ensure healthy seed a system of certification is used by the Agricultural Departments in the United Kingdom and Eire. Certificates are of three kinds: "SS" (Stock Seed) which is seed of the highest grade intended mainly for seed production, "A" (first quality commercial seed) and "H" healthy commercial seed). After the certificate letter, the country of origin is indicated, thus: Scotland "(Scot)," England "(E)," Wales "(W)," Northern Ireland "(Nor. Ir)," Eire "(Eire)," or Isle of Man "(I.O.M.)." Finally, "N.I." is added in the case of those varieties which are not approved as immune from Wart Disease. Thus, a certificate designated "A

(Scot) " would indicate seed potatoes of first quality, commercial standard, grown in Scotland, and of a variety immune from Wart Disease; " H (E) N.I.", healthy, commercial seed potatoes grown in England, but of a variety not approved as immune from Wart Disease.

The field inspection standards adopted by the several Departments for the issue of these certificates are now in very close agreement.

The attention of all seed potato merchants and growers is drawn to the Seeds (Amendment) Regulations, 1944, which lay down the classification for seed potatoes and set out the particulars which must be stated on every sale or exposure for sale of seed potatoes in England and Wales.

When ordering seed potatoes, growers should state the variety, class of seed, country of origin and size of tuber required. As a rule one ton of seed is required to plant an acre of ground. For earlies planted in 24 in. rows with a foot between the setts, 25 cwt. may be required, whilst for main crops planted 16 in. apart in the row, with 28 in. rows, 18 cwt. may be plenty.

Size of Seed—The most economical size of seed potato is comparable to a hen's egg, and will weigh about 2 oz. Each tuber may be cut into small pieces, each of which should contain at least one healthy sprout. When cutting tubers it is advisable to leave the cut sections in a cool, dark place for a few days before planting. This allows a protective layer of cork to form over the cut surface.

Recent findings suggest that, as an economy measure with a sample of large seed, cutting can be omitted. Large setts should simply be spaced farther apart in the row, the important factor influencing yield being weight of seed per acre and not the spacing between setts and rows.

The practice of sprouting seed potatoes leads to higher yields per acre, and is to be encouraged. For this purpose the tubers should be boxed as soon after lifting as possible and kept over winter in a glass chitting-house, or other well-lighted room where temperature can be maintained above 40° F.

Normally, potatoes occupy part of the root break in the rotation, but in certain parts of the country where conditions are very favourable for their growth, rotations which grow a higher proportion of potatoes are followed.

Cultivations—A deep, friable tilth should be obtained and repays every effort.

Manuring—Farmyard manure, which is well-suited for potatoes, should be applied and ploughed in prior to cultivating, or it may be applied in the rows immediately before planting. In addition to dung for second earlies and main crops, the following fertiliser mixture is advisable:—

	cwt. per acre
Sulphate of ammonia	3
Superphosphate	3
Muriate of potash	2

For earlies, which have to be forced to maturity rapidly, 10 cwt. per acre or more of a compound fertiliser may be given. The following is a common mixture used in many of the early districts:—

	cwt. per acre
Sulphate of ammonia	4
Superphosphate	5
Muriate of potash	1

Planting—Planting may be done by hand or machine, main crops being planted at the end of March onwards. About 2 weeks after planting, light harrows can be run over the land to level the ridges and kill small weeds, and inter-row cultivation will continue as long as it is possible without damaging the plants.

Lifting—Lifting will commence in early districts at the end of May, whilst main crops will be lifted from September onwards.

The traditional method of storing is in clamps, but equally satisfactory is the use of sheds and barns, where insulation of the walls with straw bales to protect the tubers from frost may be necessary.

Yield—The average yield per acre varies from 6–8 tons per acre, but on good soils in favourable seasons, 16 tons or more may be obtained.

CABBAGE

The large number of varieties available may be grouped as is shown on the facing page.

Early Varieties—Winningstadt, Early Drumhead, Early Express, Early Sheepfold, Enfield Market.

Seed sown March, transplanted April to May, ready for cutting August to September.

Seed sown May, transplanted June to July, ready for cutting October.

Seed sown August, transplanted October, ready for cutting July.

Late or Main Crop Varieties—Cattle Savoys, Drumheads, Late Ox-hearts, Purple Flatpoll.

Seed sown March, transplanted April to May, ready for cutting November onwards.

Seed sown nursery bed August, transplanted in October, ready for cutting in July or transplanted following April and ready for cutting from September to December.

Quantity of Seed per Acre—4 lb. per acre in rows 24–30 in. apart. Single to 18–24 in.

Sown in a nursery bed 1 lb. of seed supplies sufficient plants for an acre of land. When plants are purchased 5000 to 10,000 per acre are required according to spacing. The advent of an efficient mechanical transplanter has greatly increased the practice of transplanting.

Suited to stiff soils, and forms a capital fallow crop for such. Considered by some superior to turnips for feeding purposes.

Manuring—Responds to generous manuring. In addition to farmyard manure (up to 20 tons per acre) the following mixture of fertilisers should be applied prior to sowing or planting out:—

	cwt. per acre
Sulphate of ammonia	3
Superphosphate	3
Muriate of potash	1

During the growing season two top dressings of $1\frac{1}{2}$ cwt. Nitro-chalk per acre usually prove worth while. Being a "cleaning" crop, cabbages usually occupy part of the root break.

Yield—On good land 30 tons per acre, but up to 60 tons can be obtained. For early varieties, 20 tons per acre.

RAPE

Grows on a wide range of soils, succeeding best in the cool, damp districts of the north and north-west. Subject to mildew in mild climates.

Varieties—The varieties grown may be Giant rape having smooth leaf and long tap root and most suitable for land in good heart or Essex Dwarf with a rough leaf and fibrous root suitable for the heavier classes of land.

Used frequently as a catch crop it produces keep three months after sowing. Often sown in mixtures with soft turnips or mustard or ryegrass.

Cultivations—These usually follow the lines adopted for any root crop.

Manuring—In addition to dung the following mixture of fertilisers may be applied prior to sowing the seed:—

	cwt. per arce
Sulphate of ammonia	1
Superphosphate	2

If dung is not available 1 cwt. per acre of sulphate of ammonia may be given in addition.

Seeding—Seeding takes place at any time from March to September, sowing in rows 10–12 in. apart at 2–4 lb. seed per acre or broadcasting at 10–12 lb. per acre. Sown as a nurse crop for seeds, it should not exceed 2 lb. per acre. The yield of green fodder is in the region of 10 tons per acre.

KALE

Marrowstem Kale has been produced by crossing Kohl-rabi and Thousand-headed kale. It is usually grown as part of the root break and thrives on a wide range of soil conditions, preferring deep soils in a stage of high fertility.

Thousand-headed Kale is a much-branched plant with numerous plain, uncurled leaves. It withstands more severe winter conditions than Marrowstem kale and for this reason is usually reserved for feeding after Christmas, by which time Marrowstem kale has become woody and fibrous and low in feeding value.

Rape Kale and **Hungry Gap Kale** are hybrid varieties grown in a manner comparable to the other kales, but being

particularly useful for feeding in late spring and even until June.

By using all the types of kale mentioned it is possible to secure a succession of succulent feed from September to June.

Cultivation—Usually these crops are grown in rows 20–24 in. apart on the ridge or on the flat, sowing 4 lb. of seed per acre from March onwards. Both Marrowstem kale and Thousand-headed kale are frequently sown broadcast. The seed may be sown in a nursery bed and the plants transplanted under favourable weather conditions. 1 lb. of seed provides an adequate number of plants for an acre of ground. This method has the advantage of good control over turnip flea beetle since adequate protection from the pest can be given in the nursery bed by dusting with an insecticide and, moreover, it permits cleaning operations to continue until planting out takes place.

Manuring—The kales are gross feeders and, in addition to farmyard manure—up to 20 tons per acre if available—the following fertilisers should be applied prior to sowing the seed:—

	cwt. per acre
Sulphate of ammonia	3
Superphosphate	3
Muriate of potash	1

Additional top dressings, say, two each of 2 cwt. Nitro-chalk per acre, may be justified when heavy yields of very leafy crops are required.

Singling—Where grown in rows, inter-row cultivation continues as long as possible without damaging the crops. Singling commences as soon as the first rough leaves are formed, but is now seldom practised.

Kales may be folded off by cattle or sheep or the crop may be cut and carted home for housed cattle. Folding with the aid of an electric fencer is becoming increasingly popular owing to the low cost of labour involved. Marrowstem and Thousand-headed kale make excellent silage when chopped and this is particularly useful for feeding late in spring.

Yield—The average yield of Marrowstem kale is 20 tons per acre, but with generous fertiliser treatment 40 tons per acre is not uncommon. Thousand-headed kale usually yields about 10–15 per cent. less than Marrowstem kale.

BROCCOLI

Definition—Cauliflower, including broccoli, is a form of the cabbage species (Brassica oleracea) in which the terminal bud is enlarged in the early flowering stage. The head thus consists of the curd, that is, the short swollen inflorescence branches bearing tightly-packed, early-stage flower buds, surrounded by the upper leaves. " Broccoli " is the growers' name for the forms coming to harvest in winter and early spring, as opposed to summer and autumn cauliflowers. (Sprouting broccoli are quite distinct forms in which the numerous small curds are borne on side branches arising from the leaf-axils.)

Area in which Broccoli is grown—Mid-winter varieties in Cornwall and coastal areas of Southern England and South Wales. Early spring varieties in Kent and Lincolnshire. Late spring varieties in East Anglia, Vale of Evesham and horticultural areas of the North of England.

Soils—The crop is adaptable and succeeds equally well on soils ranging from light sandy soil to heavy clay.

Cultivations—The seed is sown in April in drills or beds for transplanting in July. The usual cultivations are made as for root crops. Following row crop cultivations after transplanting it is usual to ridge to assist drainage and root formation during the autumn.

Varieties—Roscoff varieties are suitable for coastal areas in the South and West of England and six types give a sequence for cutting from December to May.

Angers (Peerless) varieties are grown in south-eastern areas.

Hardy Broccoli—April Queen, Leamington, St. George, May Blossom and June are well-known varieties. Many growers save their own stocks of seed.

Seedbed—Half to one pound of seed is allowed per acre and is sown at 1 oz. per 100 ft. to 150 ft. run of drill. Seed should be dressed against flea beetle.

Transplanting—During the month of July gives the best results. Spacing varies from 2 ft. 3 in. to 2 ft. 6 in. square. Approximately 8,000 plants per acre are required. Dipping

in one of the recommended insecticides will prevent Cabbage Root Fly damage.

Manuring—Up to 20 tons per acre of dung is usual when available. Alternatively, " bulky " organic manures are used. Fertiliser application just prior to transplanting:—

	cwt. per acre
Sulphate of ammonia	1–3
Superphosphate	2–3
Muriate of potash	2–3

(Where the crop follows early potatoes no additional base dressing is used.) Top dressing just prior to heading, with potash nitrate or Nitro-chalk, is commonly practised by many growers.

Yield—200–300 crates per acre (average two dozen per crate).

MAIZE

Maize may be grown for green fodder or ensiling in districts subject to drought. White Horse Tooth and the American hybrids, e.g., Wisconsin 240 and Canbred 150, are recommended.

The seed should be sown when danger of frost is over (early May) at 56–84 lb. per acre, 2 in. deep, in rows 24 in. apart. The manuring should be generous and comparable to that given for kale.

An average crop gives 20–25 tons per acre of green crop. Good crops yield 35 tons.

LUPINS

Lupins may be grown on poor land for green manuring. White, yellow and blue varieties are available. The Sweet lupin has been used for forage.

Sow in April, 60–120 lb. per acre in rows 20 in. apart, or the seed may be broadcast.

If grown for seed cut before fully mature to prevent shedding. Yield of seed 12–18 cwt. per acre.

WHEAT

Wheat succeeds best in dry climates and is accordingly found to the greatest extent in eastern districts of England

and Scotland. The chief proteins of wheat are gliadin and glutenin.

Varieties in each of the following sections are shown in order of probable yields under average conditions in standing disease-free crops.

Winter Varieties—Cappelle Desprez, Minister,* Hybrid 46, Bersee, Banco, Dominator, Holdfast,† Yeoman.†

* suitable for biscuit making.
† high bread making quality.

Spring Varieties—Koga II, Atson, Peko.

Fylgia II and Svenno are recommended where fairly long straw is required with very early maturity.

Manuring—Manuring depends upon place in rotation. After roots or fallow merely nitrogenous top-dressing; after ley farmyard manure is commonly applied; after straw-crop sulphate of ammonia 1–1½ cwt., superphosphate 2–3 cwt., muriate of potash ½ cwt. or concentrated complete fertiliser in a combine drill.

Quantity of seed to sow per acre, 2–3 bushels = 9–13½ stones, in drills 6 in. to 9 in. apart, and 1 in. to 1½ in. deep. Weight per imperial bushel (Ministry of Agriculture) average, 62·3 lb. Average head of wheat 20 spikelets; each spikelet 3 grains, total head 60 grains. Average yield of grain per acre (1945–54), 20·8 cwt.; straw, 25–30 cwt. Proportion of grain to straw, 1 : 1 or 1¼. Proportion of dressed corn to tail corn, 10 : 1.

One quarter of wheat weighing 500 lb. yields on grinding:—

	lb.		per cent.
Flour	380	=	76·0
Bran	26	=	5·2
Middlings	50	=	10·0
Sharps	34	=	6·8
Loss	11	=	2·0

BARLEY

Barley is suited to medium to light soils, preferably with a good lime content. Frequently grown after a root crop

but not uncommonly after wheat. It has a well-developed but not very deep root system and in consequence a fine seedbed is essential.

The following varieties are recommended:

Spring Varieties—Rika,* Proctor, Freja,* Spratt Archer, Earl, Plumage Archer.

Winter Variety—Pioneer.

* of no value for malting.

Manuring—Needs special care to secure malting sample. Usually 2–4 cwt. superphosphate and 1 cwt. muriate of potash per acre. Nitrogen is seldom given except when barley follows a cereal when $\frac{3}{4}$–$1\frac{1}{2}$ cwt. sulphate of ammonia may be justified.

Quantity of seed per acre, $2\frac{1}{2}$ to 4 bushels = $1\frac{1}{4}$ to 2 cwt. per acre; if drilled 6–9 in. drills, 2 to $2\frac{1}{2}$ bushels = 1 to $1\frac{1}{4}$ cwt. per acre. Optimum time of sowing February to middle of March; for winter sorts, early October.

Weight of bushel, 56 lb. Average head, 32–36 grains. Proportion of kernel to husk, 90 per cent. to 10 per cent. Average yield of grain per acre (1945–54), 19·5 cwt.; straw, 20 to 25 cwt. Proportion of grain to straw, 1 : $1\frac{1}{4}$.

Barley malt is made by immersing the grain in water for from 45 to 65 hours and then allowing it to germinate on a malt floor. During this time enzymes are liberated within the grain, one of which dissolves the matrix of the cells of the grain in which the starch granules are embedded, and thereby facilitates the action of diastase at a later stage. The plumule and radicle of the germ also develop, the latter with many rootlets. When this process is advanced to the requisite stage the grain is dried at a sufficiently high temperature to cause a suspension of germination without killing the enzymes; it is then screened to remove the rootlets, and in this condition is known as malt. In the process of malting small amounts of dextrine and maltose are formed but the main change of starch into soluble sugars is effected by diastase in the brewing mash tun. About 35 per cent. of the proteins or nitrogen compounds are also rendered soluble and appear in the final beer in this condition. The malting operation occupies 10 to 15 days.

OATS

Most versatile of cereal crops, but prefers cool, moist districts. Will grow on all classes of soils but best suited to clay loams. Will tolerate soil acidity.

Spring Varieties—Blenda, Sun II, Maldwyn, Eagle, Milford. In northern and western districts where fertility is not too high: Opus II.

Winter Varieties—S.147, Picton, S.172, Powys.

Proportion of husk to whole grain: 20 to 35 per cent.

Manuring—After roots or ley seldom necessary; after straw crop fertilise as for wheat.

Quantity of seed to sow per acre for common varieties, 3 to 6 bushels = $1\frac{1}{8}$ to $2\frac{1}{4}$ cwt. per acre in drills 6 to 9 in. apart or broadcast. Optimum time to sow: October for winter and February to March for spring varieties, usually after ley or another cereal. Average yield of grain per acre (1945–54), 18·2 cwt. per acre; straw, 20 to 30 cwt. Grain to straw ratio, 1 : $1\frac{1}{2}$ or 2.

RYE

Suits poor and light sandy soils and will grow up to 1200 feet above sea level. Often grown on peat land where oats would lodge.

Winter and spring varieties occur, but in this country spring varieties are seldom grown. The winter varieties used are Pearl, Steel, King II, Petkus Winter (short).

Quantity of seed to sow per acre, 2–3 bushels. Optimum sowing time September and early October. For soiling and sheep folding sow up to 4 bushels per acre in August or September. Weight per bushel, 54 lb. Number of grains per bushel at 55 lb., 1,161,600. Average yield of grain per acre (1945–54), 16·6, cwt.; straw, 35–40 cwt. Proportion of grain to straw, 1 : $1\frac{1}{2}$ or 2.

Should be cut for grain only when dead ripe. Will not "shatter" readily. For soiling should be cut immediately after it shoots; often mixed with tares for soiling or sheep folding. Straw tough and wiry; excellent for thatching: is crossed-fertilised in contra-distinction to the other English cereals which are self-fertilising. The chief proteins of the

grain are gliadin and glutenin but, unlike wheat, gluten is not formed when the flour is mixed with water.

MIXED CORN

Mixed corn is frequently sown where conditions are unfavourable for straight cereals. " Dredge " is usually a mixture of barley and oats and " Mashlum " one or more cereals but chiefly oats with beans or peas. The total seeding is about 15–16 stones per acre and the cultivation follows the lines already indicated for the cereals.

BEANS

Varieties are divided into winter and spring groups, the latter ripening 2–3 weeks later, the former having the better tillering capacity. Specific varieties have not yet been developed but research is in progress.

Seed rate is $1\frac{3}{4}$–2 cwt. per acre for winter and 2–$2\frac{1}{4}$ cwt. for spring-sown varieties. May be drilled in rows 7 or 21 inches apart or broadcast and ploughed in, usually between two corn crops or in place of clover ley. Crop does well on ploughed out grassland. Sowing dates mid-October or mid-February. Chief manurial requirement is for phosphate. Soil must be well supplied with lime. Dung is beneficial and, in addition, for most soils 6–10 cwt. per acre basic slag or 3 cwt. superphosphate with 1 cwt. muriate of potash. Average yield of grain, 15·6 cwt. per acre (1945–54), but 30 cwt. not uncommon; straw, 25 cwt. per acre. Ratio of grain to straw, 1 : $1\frac{1}{2}$.

PEAS

The crop may be grown for (*a*) stock feeding, (*b*) packing, or (*c*) picking green. Varieties for (*a*) Dun, Maples, including Minerva and Marathon; (*b*) Harrison's Glory, Emigrant, Servo, Rondo; (*c*) Laxton, Onward, Lincoln, Gladstone.

Seeding usually February-March at $1\frac{3}{4}$ cwt. per acre in rows 14–18 in. apart and 2 in. deep. Seed should be dressed with thiram dust to prevent rotting in the soil. In favourable districts sowing in October-November is successful. Lime is essential. For average conditions 2 cwt. per acre superphosphate and 1 cwt. per acre muriate of potash is adequate.

Average yield grain, 13·0 cwt. per acre, 20–25 cwt. straw. Green peas yield 70 bags (40 lb.) as first earlies, 120 bags second earlies and 150 bags for main crops.

VETCHES OR TARES

Winter and spring varieties are listed but little is known of the difference between them. The former are regarded as the hardier. Grown mainly for forage either alone or in mixture with cereals. The land should be manured as for peas. Winter vetches are sown September-October, spring vetches from February to April, using $1\frac{1}{2}$ cwt. per acre of seed. Bird scaring may be necessary. More commonly grown in mixture with oats.

Grown alone, vetches produce 12–18 cwt. of seed per acre.

BUCKWHEAT

Two cultivated species—Fagopyrum esculentum, common buckwheat; Fagopyrum tartaricum, Tartarian buckwheat.

Under Fagopyrum esculentum there are three varieties, Common, Silver Grey and Japanese, which differ in the height and bushiness of the plant, and in the colour and shape of the seed.

Seed of common buckwheat is dark brown, triangular in cross-section, and with sharp angles, while in varieties of tartaricum the seed is longer with rounded angles and wavy outline, and greyish in colour.

Quantity of seed to sow per acre, 1 to 2 bushels = $4\frac{1}{2}$ to 9 stones per acre; sown from middle to end of May. Buckwheat is very susceptible to frost damage. Yield of grain per acre, 10–12 cwt. according to fertility of soil. Grain approximates oats in composition, but has a slightly higher fibre content; is valuable for poultry feeding.

FLAX

Cultivated species—Linum usitatissimum, L. angustifolium and L. crepitans.

The latter two species are cultivated to a limited extent abroad, but L. usitatissimum supplies the flax and linseed of commerce, and is the only species grown in the British Isles.

L. usitatissimum comprises two major groups, the seed flaxes, and the fibre flaxes, the former being characterised by

a much branched habit of growth, later maturity, shorter stems and higher seed yield than the latter in which the stems are unbranched for the greater portion of their length.

Flax is only grown on contract for processing factories and the seed is supplied to the grower by the factory. Government support for the industry has now been discontinued and many factories have closed down.

Varieties commonly grown are Stormont Gossamer, Stormont Cirrhus, Liral Monarch, Liral Prince, Norfolk Earl and Wiera.

Quantity of seed to sow per acre, 6–8 stones. Sow mid-March to mid-April in southern England, in northern districts mid-April to mid-May, drilling is preferable; preparation of land before sowing should aim at a fine, firm, clean seedbed and the seed should be lightly harrowed in and rolled to encourage even and prompt germination.

Weight of seed per bushel, 56 lb. Number of seed per lb., 108,000. Average produce of straw per acre, 2–3 tons. Average produce of seed per acre, 4 cwt. Average produce of scutched fibre per acre, 30 stones.

In the crop rotations flax is generally taken after a white straw crop or after ley. Best suited to medium loams; on land which is too fertile fibre quality is inferior and the crop tends to "lodge." It is usually grown on the reserves o plant food in the soil.

Flax should be pulled at the time when the basal stem-leaves start to fall off and tied into round sheaves or butts. After drying they are immersed in soft water to ret. The retting process is continued long enough to enable the fibre bundles to be readily separated from the other stem tissues when scutched, but if continued too long the individual fibres of the bundles tend to separate on scutching and much tow will then be produced.

LINSEED

Recommended varieties are: Dakota, B.1528 (U.S.A.), Daehnfeldt Elite No. 6 (Denmark), Svalof Oil Flax II and Valuta (Sweden).

Of these Svalof Oil Flax II has proved the highest yielding variety in recent series of trials.

As with flax the crop is grown usually on plant food

reserves in the soil, but for best results the following manuring is recommended:

	cwt. per acre
Sulphate of ammonia	1
Superphosphate	3
Muriate of potash	1

Linseed can be sown broadcast at 120 lb. per acre or drilled at 60–70 lb. The seed should not be buried deeply, ½–1 in. being ample in most cases. It is well suited for growing on ploughed out grassland, being relatively immune to wireworm attack and rabbit damage.

The crop should be cut when the seed in the ripest capsules is plump, shiny and pale brown in colour. If cutting is delayed beyond this point much seed is likely to shed. Small sheaves should be made to facilitate drying and the threshing drum needs careful setting. The straw is useless for feeding or bedding but the chaff can be fed direct or used for making linseed jelly. The yield of seed is usually about 10 cwt. per acre.

LUCERNE

Cultivated species—Medicago sativa.
In the U.S.A. known by the Arabic name Alfalfa.

Early—Du Puits, Socheville, Chartrainvilliers, Flamande. These strains give higher yield of total dry matter and of crude protein than other types.

Mid-Season—Provence, Hungarian, Marlborough, Marais. 7–14 days later in spring.

Late—Grimm, Ontario Variegated, Rainy River. 1–2 weeks later than mid-season.

Extra Late—Medanos. 3–4 weeks later than early strains.

Mostly grown in the eastern counties where its drought-resistant features are of great value.

It is a perennial and where properly managed yields three to four cuts annually for a period of years.

Grows on a wide range of soil types provided the land is clean, well drained and not acid. Phosphatic and, on light

land, potassic fertilisers also should be applied before sowing and annually during the life of the crop. A fine, firm, clean seedbed is essential, and on land which has not grown lucerne successfully before, the seed should be inoculated prior to sowing with a root nodule " culture."

May be grown as a pure crop or in association with other forage species.

Quantity of seed per acre, 15–20 lb. in rows; sown in April with or without a cereal " nurse " crop, or in July without a " nurse " crop. Good mixtures are: 14–16 lb. lucerne, 1–3 lb. cocksfoot and ½ lb. wild white clover; timothy or meadow fescue may be substituted for the cocksfoot. Weight per bushel, 60–62 lb. Seeds per lb., 205,000. Average yield of fodder per acre, 10–20 tons, green; 2–5 tons hay. Average yield of seed per acre, 6 bushels.

The time of cutting of lucerne is of great importance. The first cutting may, with advantage, be taken at the early bud stage, but later cuts are best taken at the early flowering stage to allow the root stocks to replace their food reserves. It is vital the root stocks should not be exhausted of winter reserves by having to produce young growth late in the season. Hence, cutting should be avoided between early September and late October. When growth has ceased a final cut can be made.

SAINFOIN

Is known by such other names as St. Foin, Cock's Head and Holy Grass. It is a valuable leguminous plant in the sheep districts of southern England. It can be used for cutting and feeding green in summer, for grazing, or for hay. Where clover-sickness disease is prevalent it is frequently grown as a substitute. The hay is much sought after for bloodstock, and as a drought resister sainfoin is second only to lucerne. A warm and dry climate is essential and, provided an adequate supply of lime is available, it grows satisfactorily on a variety of soils. It fails utterly on wet cold land.

Varieties—There are two main types, namely, Common and Giant.

Common sainfoin is a perennial which is usually left down for three or four years. It attains a height of about 2 ft. and flowers in late May or June, and is best used for grazing

as it produces very little aftermath when mown. Four regional types are known, Cotswold, Hampshire, Vale of Glamorgan and Eastern Counties. Cotswold is very persistent, prostrate in habit and moderately vigorous. Hampshire is coarser and more vigorous than Cotswold and equally persistent, whilst Vale of Glamorgan resembles Hampshire but is more prostrate and more persistent. The Eastern Counties type is more vigorous than Hampshire but less persistent, and is really intermediate between Common and Giant sainfoin. Several local stocks within these regional types have a good reputation.

Giant sainfoin gives much more bulk than Common, but only lasts for two or three years. It establishes itself quickly, gives two crops of hay in a season and is well suited for rotation cropping.

Sainfoin usually replaces the clover ley in the rotation and is commonly sown under barley as a nurse crop. Mixtures of sainfoin with leafy timothy or meadow fescue are frequently sown in preference to the pure crop. Clean land is essential if the crop is to remain down for a number of years. Prior to sowing, an application of phosphate together with potash is advisable.

Sowing the Seed—The seed is usually drilled in rows about 7 in. apart and about 1 in. deep, from February to May. If drilled deeper than this, though it germinates the shoots may fail to reach the surface and die underground.

Seed may be obtained in the husk (unmilled) or with the husk removed (milled), the advantage of milled seed being that it has a higher germination. Unmilled seed always contains some husks that are either empty or only partially developed, and a further disadvantage is that it is difficult to eliminate large weed seeds such as brome grass, or burnet, unless the seed is first milled. It is essential to use only fresh-coloured seed which is plump and light brown in colour, for when the seed is black or shrivelled it denotes that it is either old or has been harvested badly.

The seed rate is 56 lb. per acre for milled seed or 100 lb. per acre if the unmilled seed is used, but recent work has shown that when the seedbed is carefully prepared these quantities can be reduced.

The usual practice in the eastern counties is to grow sainfoin as a pure crop, but in the south and west of England

it is a common constituent of temporary or permanent ley mixtures.

The following mixtures have given good results:—

Two Years' Ley:—

Perennial Ryegrass...	6	lb.	per acre.
Cocksfoot	12	,,	,,
Giant Sainfoin	10	,,	,,
Dorset Marl Red Clover	4	,,	,,
Alsike Clover	2	,,	,,
White Clover	2	,,	,,
	36	,,	,,

Cotswold Mixture:—

Perennial Ryegrass...	14	lb.	per acre.
Cocksfoot	7	,,	,,
Rough-stalked Meadow Grass ...	3	,,	,,
Timothy	3	,,	,,
Common Sainfoin	4	,,	,,
Cotswold Late-flowering Red Clover	4	,,	,,
Wild White Clover	1	,,	,,
	36	,,	,,

Hay—The crop must be cut as soon as flowering begins for delay means a lower quality and also impairs the future cropping capacity of the plant. Like lucerne, it requires careful handling in the field to avoid loss of leaf. The average yield of hay is about 30 cwt. per acre. When the crop is cut for seed the yield is 5 to 6 cwt. per acre of seed in the husk.

CRIMSON CLOVER (Trifolium)

This is one of the cheapest forage crops which can be grown when rapidity of growth and early maturity are desired. It is an annual, 1 to 2 feet in height, but is confined to the south of England on account of its susceptibility to severe weather. The crop does best on loamy soils and the deeper soils in general.

Although it is grown in chalk districts it is always on the lower gravelly soils, for on thin chalk it is not satisfactory.

There are four varieties, early, medium and late strains of red trifolium and a late white trifolium. When sown at the same time these varieties are ready for consumption in sequence by the following May. Late red trifolium is ready about the same time as the late white variety, whilst early red comes to feed about a fortnight before either.

Trifolium is chiefly grown as a catch crop and is usually sown on the stubble after winter cereals or silage crops.

The stubble is merely harrowed once or twice, for elaborate cultivations producing a deep tilth are unnecessary and, in fact, undesirable.

Manuring produces an earlier and bulkier crop, although as a rule the crop will have little, if any, fertiliser given to it. A further advantage of a slight dressing of artificials is that the feed remains succulent for a longer period.

The following mixture is suggested:—

Sulphate of ammonia	½	cwt.	per acre.
Superphosphate	3	,,	,,
	3½	,,	,,

which should be applied prior to sowing the seed.

Early red trifolium may be sown in July, August or September, the other varieties usually being sown in August or September. As a rule the earlier the seed is sown the better, as a forward plant is in better form to withstand slugs and other damage during the winter. 20 to 24 lb. of seed per acre is required, and in many instances this is mixed with Italian ryegrass to provide a crop for folding with sheep or pigs. In mixture 15 lb. crimson clover and 5 lb. per acre Italian ryegrass give good results, and when sown in June is ready for grazing in July, or can be cut for hay in August of the same year. The seed is generally broadcast, harrowed in, and well rolled. A good firm seedbed is desirable and the seed should not be buried deeper than one inch.

Sheep are usually hurdled on small areas of crimson clover, and care is necessary to feed it off before an advanced stage of growth is attained, for then the flowers are hairy and may cause the formation of hair balls. It is ready for folding early in spring and is, therefore, of considerable value for fat-lamb production or for pushing on ram lambs. In

feeding, care is necessary not to allow them on when the foliage is rimy with frost.

Any surplus to folding needs can be made into hay, provided the crop is cut before the plant becomes woody and the flowers hairy. Fine weather is most desirable, for crimson clover soon develops mildew. When harvested for seed the straw after threshing is fit only for litter, as the woodiness of the stems make it unsuitable for feeding to stock. When feeding the hay it is a wise precaution to feed meadow hay along with it to avoid any trouble with the stock which might consume too much.

HOPS

Principal Varieties—These are grouped for marketing purposes as follows:—

1. *Goldings*—Early Bird, Bramling, Canterbury Golding, Eastwell Golding, Petham Golding, Rodmersham Golding, Mathon.

2. *Golding Varieties*—Cobbs, Tutsham.

3. *Fuggle*—Over 70 per cent. of the English hop acreage is planted with this variety.

4. *New Varieties**—Early Promise, Northern Brewer, Pride of Kent, Brewer's Gold, Bullion Hop, and others.

The hop is a perennial, producing long climbing stems (bines) which die down to within about 6 in. of the root-stock in the autumn; the basal portions of the stems are used as cuttings for propagation. These are grown for the first year in nursery beds. The hop is dioecious; the female inflorescences (cones) are the " hops " of commerce, but a proportion of male plants are included in plantations as the cones do not develop to their full size unless they are pollinated; usually 1 male to 200 female plants.

Soil—A wide range but a well-drained, slightly heavy loam resting on a porous subsoil is preferable. Soil-moisture is important; hops will not thrive on dry soils.

Spacing and Training—Hops are planted on the squar at about 6½ ft. apart or 4–5 ft. apart in rows with a space of

* Raised by Professor Salmon at Wye College.

6½–9 ft. between the rows. The bines are trained up coir yarn (coconut fibre string) supported on an overhead system of wirework at a height of 13–14 ft. Two bines are usually trained up each string, the number of strings varying from two to four per plant according to the system of planting.

(The new varieties Brewer's Gold and Bullion are very vigorous in growth and must be grown with wider spacing, 7–8 ft., and high wirework, 14–16 ft. and only one bine per string.)

Cultivation—The land is ploughed, throwing the furrows away from the rows of plants, in spring. In March the top of the rootstock is exposed by hoeing and the bases of the previous year's bines are cut off near the rootstock. Cultivation, commencing at a depth of about 6 inches, is gradually reduced in depth and after early July is very shallow. The bases of the bines are earthed-up slightly in June. Autumn treatment aims at the prevention of waterlogging the plants on flat heavy land by throwing the soil into low ridges with the plant on the crest of the ridge. On lighter soils the land is ploughed toward the rows of plants in October or November.

Manuring—Should be liberal and, while individual soils may require special treatment, the annual requirements for average land are:—

	lb. per acre
Nitrogen (N)	250–300
Phosphoric acid (P_2O_5)...	230
Potash (K_2O)	200

Sufficient lime should be applied to keep the soil in a nearly neutral condition, pH 6·5 to 7·0, and sufficient organic matter to preserve the soil structure.

Picking—The hop produces its flowers ("burrs") in mid-July; the inflorescences develop into cones which ripen early in September The ripe cones are picked by casual labour paid at an agreed price per basket of approximately one bushel, or by picking machines, which are being used increasingly to reduce labour costs. A bushel of green hops weighs from 5–6 lb. Picking takes about three weeks. Average yield 11–14 cwt. dried hops per acre.

Drying—Hops are kiln dried immediately after picking, their moisture content being thus reduced from about 80 to

about 6 per cent. The hops are placed to a depth of 10–24 inches upon a loosely-woven horse-hair cloth supported on an open slatted floor and a current of heated air passed upwards through the load by natural convection, or by forced draught produced by a fan. Sulphur is burned below the hops at the commencement of drying to improve the appearance of the hops and to modify their aroma. The temperature is low at the commencement, about 100° F., rising to a maximum of 145 to 155° F. in four to five hours. The process takes about ten hours per load. Two loads are dried in a 24-hour day. The dried hops are pressed into " pockets," about 2 ft. in diameter and 6 ft. in length, each containing approximately $1\frac{1}{2}$ cwt. of hops. These are each marked with a serial number, the name of the grower and the parish and district in which the hops were grown.

Marketing—Hops can. in England, be sold only through the Hops Marketing Board. Each producer is registered with the Board and is allotted a " basic quota " founded on his production of hops in certain datum years; the ratio of this to the sum of all the " basic quotas " represents the proportion of the brewers' requirements which he is entitled to supply. Each year the estimated demand for hops is apportioned to producers in the ratio of their " basic quotas "; this amount, which may be the same as, or some percentage of, the " basic quota," is known as the " annual quota." If a producer's crop is less than his " annual quota " he may transfer the balance of the quota to another producer.

Hops are used for brewing and their value for preservative and flavouring purposes lies in the resins and essential oil contained in the lupulin glands—small yellow granules—which are produced within the cone.

THE GRASS CROP

GRASS represents the dominant crop in the United Kingdom as shown by the agricultural returns (June, 1955).

Total Acreage Permanent Grass	13,532,461
Total Acreage Temporary Grass	6,137,824
Total Acreage Tillage	11,300,557

The distribution of this grassland is governed mainly by climate and type of soil, which in turn influences the type of sward, although both manuring and the management of the sward as between grazing and mowing bring about marked alterations in the flora of any particular piece of grassland. Grassland provides the principal source of food for livestock during the spring, summer and autumn whilst the surplus summer growth conserved as hay, dried grass or silage is the main food for winter. Quite apart from these considerations grass is regarded as a means of conserving and building up soil fertility and improving the crumb structure of the soil by the ramifications of the vast system of roots.

A grass field is in fact a mixture of crops some of which have been sown whilst others have found their way there by a variety of means, the whole forming a community known as a sward or turf.

Provided the annual treatment meted out to this sward is reasonably uniform the botanical composition remains fairly constant. The use of fertilisers, heavy or light stocking, the difference between grazing by cattle and sheep, the pattern of grazing, all exert an influence on the composition of any piece of turf whilst as a result of neglect it may revert to bracken and heather, scrub, woodland and finally forest.

Broadly speaking grassland may be classified as uncultivated or cultivated according to the amount of treatment meted out by man. In the former class come the moors of the North and West of Britain, the Downs of the South, the Heaths of South and Eastern England and the Fens which are principally in the East. Cultivated grassland may be subdivided into (*a*) permanent grassland, and (*b*) leys, the principal distinguishing feature here being that of age.

TABLE 16

LIST OF THE PRINCIPAL GRASSES, CLOVERS AND HERBS

Botanical name	English name	Approximate weight of seed per bushel	Approximate number of seeds in 1 lb.	Duration*
Agrostis tenuis ..	Bent Grass ..	30	5,600,000	P
Alopecurus pratensis	Meadow Foxtail ..	12	490,000	P
Anthroxanthum odoratum ..	Sweet Vernal ..	16	738,000	P
Arrhenatherum avenaceum ..	Tall Oat Grass ..	16	138,000	P
Cynosurus cristatus ..	Crested Dogstail ..	38	886,000	P
Dactylis glomerata ..	Cocksfoot	22	426,000	P
Festuca duriscula ..	Hard Fescue ..	23	578,000	P
Festuca elatior ..	Tall Fescue ..	24	246,000	P
Festuca ovina ..	Sheep's Fescue ..	28	1,561,000	P
Festuca pratensis ..	Meadow Fescue ..	30	236,000	P
Festuca rubra ..	Red Fescue ..	28	250,000	P
Lolium italicum ..	Italian Ryegrass ..	23	270,000	B
Lolium woldicum ..	Westernwolths Ryegrass ..	20	210,000	A
Lolium perenne ..	Perennial Ryegrass	28	223,000	P
Phleum pratense ..	Timothy	50	1,320,000	P
Poa compressa ..	Canadian Bluegrass ..	30	1,300,000	P
Poa pratensis ..	Smooth-stalked Meadow Grass ..	26	2,400,000	P
Poa trivialis ..	Rough-stalked Meadow Grass ..	30	2,235,000	P
Trisetum flavenscens	Golden Oatgrass ..	14	1,400,000	P
Medicago lupulina ..	Trefoil	66	319,000	A
Medicago sativa ..	Lucerne	62	224,000	P
Trifolium hybridum	Alsike Clover ..	66	718,000	P
Trifolium incarnatum	Crimson Clover ..	65	118,000	A
Trifolium medium ..	Zig-zag Clover ..	65	220,000	P
Trifolium minus (or *dubium*)	Suckling Clover ..	66	900,000	A
Trifolium pratense ..	Red Clover ..	65	232,000	B
Trifolium procumbens ..	Hop Trefoil ..	66	850,000	A
Trifolium repens ..	White Clover ..	66	732,000	P
Anthyllis vulneraria	Kidney Vetch ..	64	193,000	P
Lotus major ..	Greater Birdsfoot Trefoil	64	363,000	P
Lotus corniculatus ..	Birdsfoot Trefoil ..	66	412,000	P
Carum pretroselinum	Field Parsley ..	43	230,000	B
Plantago lanceolata	Rib Grass	58	—	P
Poterium sanguisorba	Burnet	28	54,000	P
Cichorium intybus ..	Chicory	36	335,000	P
Achillea millefolium	Yarrow	36	3,510,000	P

* A—Annual. B—Biennial. P—Perennial.

After a ley has been down for a number of years it will take on the characteristics of permanent grassland, although with superb management a sward may never come under the plough but have all the vigour and productivity of a ley. The most productive grasslands contain a high proportion of ryegrass, cocksfoot, timothy, meadow fescue with white clover. As deterioration sets in weed species such as bent, Yorkshire fog, fine leaved fescues with dandelions, buttercups, docks and the like will gradually gain mastery.

Grassland as we know it is an association of grasses, legumes of which the clovers are the most important, and miscellaneous plants or herbs. Some of these plants are valueless from the animal standpoint and buttercups, thistles, ragwort and the like need not be discussed at this stage. The aim of the farmer should be to secure a sward with a high percentage of the most productive grasses, clovers and herbs. Grasses are more valuable than clovers for they provide more animal food for a greater period of the year, but the clovers enrich the soil in nitrogen, " knit " the sward together by virtue of their creeping habit of growth—and this helps to prevent " burning " during drought—are richer in calcium and taken over the whole grazing season are richer also in protein.

Some grasses are early, some late in commencing growth, some best adapted for cutting, others for grazing, some palatable, others fibrous and not relished by stock, whilst some provide massive yields of forage and others are very modest in their yielding capacity.

To be of high value a grass must have a high proportion of leaf to stem, produce the maximum leafage for the maximum number of weeks each year, must withstand extremes of heat and cold, drought and waterlogging, and must be persistent despite mechanical damage due to grazing, treading and cutting. No single grass possesses all these virtues and every farmer in the light of experience and trial under the specific conditions pertaining on his farm must decide which species will best meet his requirements.

A number of strains—variously referred to as " pedigree," " bred " or " leafy "—have been produced in recent years which broadly speaking are leafier and more persistent than the ordinary " commercial " strains, although it must be conceded the latter are usually earlier in the season and

frequently more palatable. The following table gives the chief characteristics of the different species and strains now available on the British market.

TABLE 17

GRASS AND CLOVER STRAINS

Grass	Strains	Purpose	Life	Comments
Ryegrass	Characteristics	—needs fertility but is early and winter green		
Italian Commercial	Irish Ayrshire Danish New Zealand France	Grazing and/or hay	2 years	Bulky, medium quality herbage, very early in spring and late autumn growth. Strong growth in midsummer. Poorer growth in second year and deteriorates rapidly afterwards
	S. 22 (Aberystwyth)		2–3 years	Leafy and more productive than commercial types
	Short Rotation (H.I.) New Zealand		do.	As for S.22 except bulk is higher in mid-season
	Westernwolths		1 year only	Gives great bulk in first three months especially on soils of high fertility and adequate moisture. Suitable for catch cropping.
Perennial Commercial	Irish Ayrshire American	Mainly hay	Up to 3 years	Early growth but stemmy
	S.23	Grazing	4 years plus with good management	Excellent quality but low in bulk. Contribution greatest in late spring and autumn
	Kent Certified	do.	do.	do.
	Melle (Belgium)	do.	do.	do.
	Danish and Swedish	Hay and Grazing	do.	Generally superior to commercial strains
	S.101	Hay/ Grazing	4 years plus; less than S.23 on poor soils	Comparable with S.23 but more erect habit of growth. Slightly earlier
	S.24	Hay	3–4 years	Very leafy and as early as commercial strains
	New Zealand Certified Mother or P.P.	do.	do.	More leafy and more persistent than commercial strains
	Devon Eaver Cornish Eaver	do.	do.	Very comparable S.24

Grass	Strains	Purpose	Life	Comments
Cocksfoot	Very bulky grass, winter burns, drought resisting, sensitive to hard grazing in early spring, wise stocking with on and off management essential			
Commercial	Danish American	Hay	3 years plus	Early, stemmy
	S.143	Grazing	4 years plus	Late spring and autumn keep and strong midsummer growth. Moderate yield high quality
	S.26	Hay/ Grazing	do.	Good yield moderate quality
	S.37	Hay	do.	High yield moderate quality mainly in spring and autumn—strong midsummer growth
	Mommersteeg and Barenza (Dutch) and Roskilde and Hammenhog (Danish) are named Continental strains superior to ordinary Danish or American Cocksfoot			
Timothy	This is a rather late grass and does not compete well with heavy seedings of perennial ryegrass. It succeeds best on heavy peaty land in high rainfall areas. The plant is very palatable and winter green			
Commercial	Canadian American Scotch	Hay	3 years plus	Deteriorates under hard grazing. Production in middle spring and autumn. Rather stemmy, the Scotch strain is to be preferred
	S.50	Grazing	4 years plus	Very late spring and autumn growth. High quality herbage but low in quantity. High tillering capacity
	Scotia	do.	do.	Useful strain for general use
	S.48	Hay/ Grazing	do.	More versatile type
	S.51	Hay	do.	Good yield medium quality. Late spring and autumn
	Omnia (Swedish)	do.	do.	Good early hay strain
Meadow Fescue	Does not stand close and continuous grazing and demands high fertility. Combines well with timothy, good aftermath, very winter green. Make sure suited to the soil on the farm. As a rule perennial ryegrass is more versatile and more productive			

Grass	Strains	Purpose	Life	Comments
Commercial	Danish American	Hay	3–4 years	Bulky, fair quality. Early spring and autumn
	S.53	Grazing	3–4 years plus	Very good quality but low yield. Late spring and autumn with strong midsummer growth. Densely tillering and leafy
	S.215	Hay/ Grazing	do.	Fair quality, good yield, early spring and autumn
Wild White Clover	S.184	Grazing	6 years plus	Very late spring and autumn. Poor yield but good quality. Densely tillering.
	Kent	do.	do.	do. Not quite so uniform in leafiness as S.184
White Clover	S.100	Hay/ Grazing	3–5 years	Good yield, good quality, mainly mid-season and autumn growth
	New Zealand Certified Mother Seed	do.	do.	do.
	Dutch and English	Grazing	1 year plus	Mid-spring and autumn growth. Medium quality poor yield
	Ladino (American and Canadian)	do.	3–4 years	Not so valuable as S.100 except in first year after sowing when early growth provided
Late Flowering Red Clover	S.123	Hay/ Grazing	2–3 years	Very late spring and autumn, bulky, good quality
	Montgomery	do.	2 years	As for S.123 except more variable in leafiness
	Cornish Marl	do.	do.	do.
	Altaswede (Canadian)	do.	do.	do.
Broad Red Clover	S.151	Hay	1 year plus	Bulky, good quality. Mid-spring and autumn
	Dorset Marl	do.	do.	do.
	Cotswold	do.	do.	do.
	English	do.	1 year only	Bulky, fair quality early spring and autumn
Alsike	Canadian	Hay/ Grazing	1–2 years	Tolerates adverse soil conditions better than red or white clovers. Less susceptible to Stem Rot. Not so good for grazing as S.100 nor for hay as S.123

Trefoil—This is a useful species on thin calcareous soils such as the chalkland arable of East England. It is grown extensively in the short duration leys to provide both fodder and seed. It is a lime sensitive plant and does not establish well on acid soils. Trefoil (*Medicago lupulina*) is sometimes confused with yellow suckling clover (*Trifolium minus*). Both are annuals but the latter establishes itself abundantly in districts of high rainfall and on acid land.

Subterranean clover—Subterranean clover is an annual having the ability to bury its maturing seed in the surface soil. It seems to have little place in British agriculture for it is surpassed as a grazing plant by white clover and as a hay plant by lucerne, red clover and alsike.

The Herbs—The whole range of herbs known to be palatable have a distinct value in ley systems. In addition to being well liked by stock they are highly efficient collectors of plant foods, particularly minerals. Some are strikingly winter green and certain strains of burnet make abundant growth in early autumn and hold their leafage green and palatable well into the winter. The same is true of other herbs including yarrow, chicory, sheep's parsley and caraway.

Herbage Seed Production—During the past 30 years greatly improved strains of both grasses and clovers have been made available. Many of these strains are particularly persistent and very leafy in character. Their very leafiness raises a problem in regard to seed production, for some of them are extremely shy seeders. The best practice is to grow the grass in wide drills (about 2 ft. apart), to sow without a cover crop and to manure fairly heavily, for the plant maintained at an adequate plane of nutrition contributes more seed than one partially or wholly starved. The supply of lime, phosphates and potash must be adequate, and the crop provided with supplementary dressings of nitrogen at fairly frequent intervals.

If the seed production rows are sown in the spring of one year they should be well established by September that year. During August, a heavy dressing of nitrogen (the equivalent of, say, 3 cwt. per acre of sulphate of ammonia) should be applied to the row crop which is then rested completely until the winter. The aim should be to grow a big crop of grassy material which, if required, can be consumed during the

period November 15th–February 15th by the grazing animal. Alternatively, of course, it could be cut and carted indoors. The crop receives a further dressing of nitrogen (about 2 cwt. per acre sulphate of ammonia) towards the end of February or early in March, and perhaps a similar dressing in April or early May. The seed crop is cut, in the case of cocksfoot, before the middle of July; in the case of ryegrass in early August and with timothy in late August. Meadow fescue is usually ripe for cutting in early July. After harvesting, the rows should either be grazed closely or cut with a mowing machine, carting the stubble away. In some cases the stubble can be burnt with success. The fertilising and management as above is repeated for successive crops of seed. The precise amount of fertiliser depends on the crop to be grown. The indications are that cocksfoot demands a higher level of nitrogen than many of the other grasses. There has been some evidence to suggest that excessive dressing with nitrogen reduces the seed crop in timothy.

When grasses are sown in rows for seed production the seed rate should be 2–5 lb. per acre. The seed crop in the case of cocksfoot, meadow fescue and ryegrass can be combined. Timothy is best cut with a binder, put into stooks and later stacked for threshing and hulling, this being particularly true of the pasture types, some of which present real difficulties in threshing. Yields of clean, marketable seed of the leafy strains of pedigree grasses are as follows:—

	cwt. per acre	
Cocksfoot	3–7	(Yields above 10 cwt. cocksfoot seed per acre have been harvested.)
Perennial ryegrass ...	3–6	
Timothy	3–7	
Meadow fescue ...	3–6	

In the case of the legumes the method of seed production is somewhat different. Nitrogen is usually withheld and emphasis is laid on lime, phosphate and more particularly potash.

White clover is usually grown as a broadcast (or close drilled) stand, either alone or with a small seeding of ryegrass or of timothy. A common mixture is 4–6 lb. of perennial ryegrass with 3–5 lb. of white clover. The field is grazed up

to the early part of June and then shut up for seed which is harvested in August. The crop when cut has to be carefully handled and should be either cocked or dried on tripods in order to ensure the best seed. The " hay " is threshed and the seed has to be hulled after threshing before being cleaned. Yields are of the order of 100–200 lb. per acre, although with S.100 white clover yields as high as 600 lb. per acre have been obtained.

Broad red clover seed is usually harvested as the aftermath crop in the normal one-year ley. Hay is taken in late May or early June and the aftermath left for seed which may be cut and threshed by combine, or may be cut loose, placed in a stack after drying and threshed during the winter. Red clover has to be hulled after threshing and then cleaned. Late red clover has to be treated somewhat differently. The crop is grazed as with white clover until late May or the first days of June, and is then put up for seed which is ready for cutting in early September. (Broad red clover is usually later to come to harvest where it is grown as aftermath.)

Seed yields in red clover vary tremendously from about ½ cwt. per acre to as much as 7–8 cwt. per acre. The average yield in broad red clover is about 1¼ cwt. per acre and in late flowering red somewhat higher. The yield of clover seed under conditions in Britain is very variable largely because it is so dependent upon the vagaries of the weather. If the soil is very moist then excessive leaf growth is made and pollinating bees find it difficult to get at the flowers. The best clover years are usually dry ones, especially when the months of July and August are dry, this ensuring a large population of bees for pollination and also the production of a minimum amount of leafy growth.

Lucerne—The same general principles are applied to the growing of lucerne seed as with red clover. Some lucerne seed is grown in Britain and many growers take the first crop for hay and seed from the aftermath. Others cut an early silage crop and then put up for seed, this latter practice brings forward the date of harvest quite appreciably, though in a wet year the amount of leafage is often excessive and the crop, therefore, difficult to handle. Lucerne seed can be combined successfully although the traditional method has been to cut, field-dry and stack. The yield of lucerne seed

in Britain varies from ½ cwt. to as much as 2 cwt. per acre. In parts of California crops as high as a ton and even 30 cwt. per acre are common. These marked differences in yields suggest that the growing of lucerne seed in Britain should not be on any large scale, arrangements being made with other parts of the British Empire or elsewhere to grow the seed so long as the strain of lucerne finds approval.

TREFOIL—Trefoil seed is grown extensively in Southern England, especially on the chalk soils, and is normally part of the one-year ley farming system in these districts. Yields of seed vary from 3 cwt. per acre to about 10 cwt. per acre, The treatment of the crop is very similar to white and red clover although little or no grazing is done at any time. Trefoil seed has to be threshed and hulled in the manner of red and white clover. These same general principles also hold in the case of crimson clover (*Trifolium incarnatum*), sainfoin and indeed, most other legumes harvested in Britain.

ESTABLISHMENT OF LEYS

The common method is to use a cereal crop as the nurse crop. To reduce competition between the crop and the seed mixture to a minimum an early ripening, stiff-strawed variety of cereal should be selected and the seed rate should be reduced by 20 per cent. The choice between wheat, barley and oats is largely determined by the rotation. If an autumn sown cereal is used then it may be advisable to remove the flag in spring by grazing off with sheep or cattle before sowing the seeds mixture.

The seedbed should be clean, fine, firm and moist at seeding and the mixture may be broadcast or drilled in the case of spring seeding. A seeds mixture may be sown immediately after the cereal crop if a spring variety is selected though some prefer to wait until the cereal is 3 in. to 4 in. high before sowing the ley mixture since this reduces competition between the two crops.

Other nurse crops used are linseed and flax, very occasionally beans and frequently a cereal-legume mixture to be cut for silage.

Some prefer to sow the ley without a nurse crop in spring or in the mid-July to mid-August period. Under these conditions Italian Ryegrass at 6 lb. per acre or rape 2 lb.

per acre or oats at 14 lb. per acre may be used to give quick cover and promote early grazing. The manuring for the ley will largely depend on the rotation followed and the reserves of plant food in the soil. If sown alone a mixture of superphosphate 3 cwt. per acre with 1 cwt. muriate of potash is advisable. An adequate supply of lime in the soil is essential and nitrogen should be used if needed.

In localities where the average annual rainfall is over 30 inches the sowing date is very flexible, and the work can proceed with safety from March to September, but in all other areas there appear to be two very definite "safe" periods, namely mid-March to Mid-April and mid-July to mid-August. Outside these limits there is some risk attached to sowing either from drought in summer, which will kill late-sown seedlings, or from frost in winter or early spring, which will kill clover seedlings which have not had time to become a fair size.

The grazing animal has a profound influence on the successful establishment of the ley. Hoof consolidation is more efficient than the roller, whilst the droppings and urine maintain a supply of plant foods and the defoliation effected causes tillering of the grasses and the spread of white clover, thus bringing about a well-knit sward. Seed mixtures sown under a cereal nurse crop should always be grazed at least once after harvest and before the start of winter. This grazing should not be too late in the season, for sufficient time should elapse for the clovers to recover from the grazing before hard frost. In the first harvest year the management will be determined in most cases by the needs of the farm as between hay and grazing. There is a strong body of opinion that favours grazing in the first year. On the other hand, one can point to countless cases where the taking of a hay crop thus early in the life of the ley has not adversely affected the sward. It is fairly apparent, however, that when a hay crop is taken in the first year it should be a light one, cut early in the season, and then followed up by grazing of the aftermath.

In the case of seeding without a cereal nurse crop there is more definite information in favour of the admittance of stock as soon as possible—generally within six to eight weeks of sowing. It would seem that the consolidation and the defoliation encourage turf formation, whereas when the crop

is allowed to grow up for hay—tempting as this may be—the sward remains open and weed ingress is favoured. For the first grazing the choice between cattle and sheep is largely a personal one. Provided it is borne in mind that cattle, being so much heavier than sheep, are more likely to poach the land, and hence require drier soil conditions, there is little to choose between them and sheep. Sheep, if confined too closely, tend to bite into the heart of plants; cattle on the other hand pull up the herbage with their tongues. On occasions serious damage has been caused to a young ley by young cattle uprooting plants—particularly cocksfoot, which does not root so readily as the ryegrass. Equally apparent, however, has been the damage caused by sheep in other cases where their ultra-close grazing has actually destroyed the plants. Experience and prevailing conditions should determine whether sheep or cattle are used for the initial grazing of a new sward, and when recourse must be made to the mowing machine this should be done before the grasses shoot the flowering stems.

There is a wide range of seed mixtures to suit the diversity of use as between mowing and grazing and to meet the requirements of soil and climate. There are two schools of thought, one favouring a complex type of mixture, including many species, on the basis of where some fail others find conditions favourable and in the long run the ideal type of sward is established, whereas the other school tends towards a greater simplification. In the latter case mixtures may consist of about one grass and one clover. It is probably true to say that more and more farmers are, by reason of their experience with complex and ultra-simple mixtures, now seeking a compromise. It cannot be over-emphasised, however, that soil fertility and other factors are of more vital consequence than the composition of the seed mixtures. Generous fertilising is essential to secure the maximum output from any sward. Common mixtures to suit a variety of purposes are given in the following pages.

ONE-YEAR LEYS

	1	2	3	4	5	6	7	8
	lb. per acre							
Italian Ryegrass	–	6	2	6	4	4	8	–
Perennial Ryegrass ...	18	10	–	8	10	4	14	–
Timothy	–	–	14	–	–	–	–	–
Broad Red Clover ...	–	3	3	4	2	4	1	5
Late-flowering Red Clover	5	3	2	–	2	–	2	–
Alsike	2	2	–	2	2	2	–	4
Trefoil	1	–	–	–	–	2	1	4
Dutch White or S.100 Clover	–	–	–	–	2	4	–	6
TOTAL	26	24	21	20	22	20	26	19

Key to Columns

1. Cockle Park Mixture for heavy cut of hay.
2. An earlier mixture than No. 1.
3. A later mixture for conditions where Timothy is known to flourish.
4. Two cuts of hay.
5. Hay and aftermath for grazing.
6. Grazing only.
7. Grazing only (where clovers difficult to establish).
8. Grazing only (where clovers flourish).

TWO-YEAR LEY MIXTURES

	lb. per acre 1	2	3
Italian Ryegrass	–	4	3
Perennial Ryegrass (Irish or Ayrshire)	–	5	6
Perennial Ryegrass S.24	–	5	–
Perennial Ryegrass S.23	–	4	–
Cocksfoot (Danish)	–	3	2
Cocksfoot S.37	–	2	–
Cocksfoot S.26	–	1	–
Timothy S.51	16	–	–
Meadow Fescue	12	–	–
Broad Red Clover	–	2	1
Late-flowering Red Clover	4	2	1
White Clover S.100	–	1	5
Alsike	–	–	2
Trefoil	–	–	2
Total	32	29	22

Key to Column

1. For hay both years.
2. For hay and grazing.
3. For grazing both year

THREE-YEAR LEY MIXTURES

	lb. per acre 1	2	3	4	5
Italian Ryegrass	–	–	–	6	3
Perennial Ryegrass (Irish or Ayrshire)	16	12	3	8	–
Perennial Ryegrass S.23	–	–	3	2	3
Perennial Ryegrass S.24	–	–	3	–	6
Perennial Ryegrass S.101	–	–	3	–	–
Cocksfoot (Danish)	10	8	4	4	–
Cocksfoot S.26	–	–	2	4	–
Cocksfoot S.143	–	–	2	4	–
Timothy (Canadian or Scotch) ...	4	4	2	–	4
Timothy S.48	–	–	2	–	4
Timothy S.50	–	–	–	–	2
Late-flowering Red Clover—					
Montgomery	4	4	2	–	–
S.123	–	–	1	2	2
Broad Red Clover—Chilean... ...	–	–	1	–	–
Wild White Clover—					
Kentish	1	1	½	½	1
New Zealand	–	–	½	–	–
White Clover S.100	–	–	–	1	1
Trefoil	1	–	–	–	–
TOTAL	36	29	29	31½	26

Key to Columns

1. Cockle Park Mixture.
2. Modern Modification Cockle Park Mixture.
3. Modern Modification Cockle Park Mixture using bred strains.
4. For light sandy soils in dry districts.
5. For clay and peaty soils.

Lawn Mixtures—

	lb. per acre
Creeping red fescue	40
Agrostis tenuis	40
TOTAL	80

Having established the ley its maintenance in a fully productive capacity will depend upon generous fertilising, bearing in mind the need for balance between nitrogen, phosphate, potash and lime.

EARLY BITE

The longer the grazing season the cheaper the feeding of the stock. To secure an early bite select a young ley on a well-drained, sheltered site and shut up in late autumn. Apply nitro-chalk at 4 cwt. per acre about mid-February

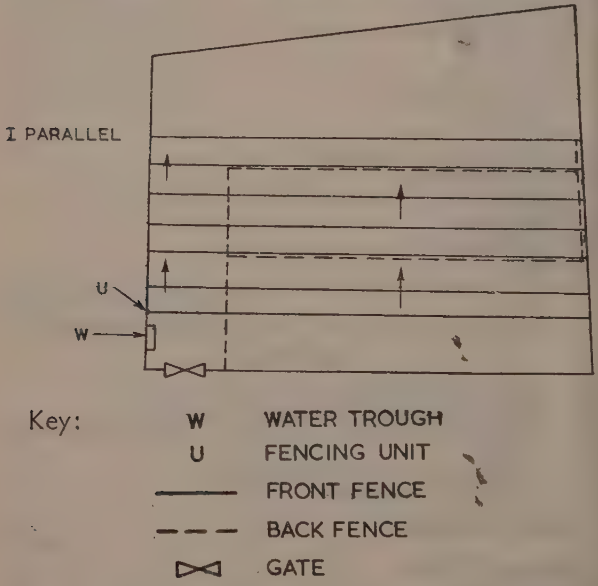
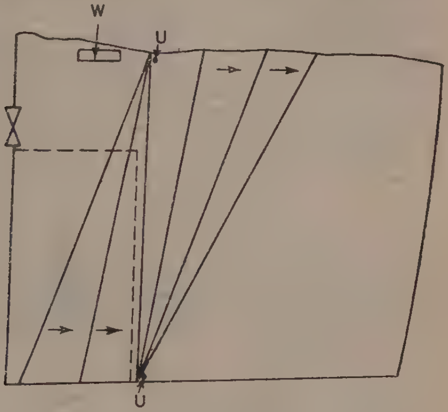


FIG. 18. In this system of controlled grazing the fence is moved forward in parallel lines.

in the south-west and south, a month later in the Midlands and a week later still in Scotland. Allow $\frac{1}{4}$ acre per cow. Autumn sown rye, Italian or H.1 ryegrass or a winter proud cereal crop may be used in place of, or as a supplement to, this early bite. The application of 4 cwt. nitro-chalk instead

II FAN



Key:

W	WATER TROUGH
U	FENCING UNIT
———	FRONT FENCE
— — —	BACK FENCE
⋈	GATE

FIG. 19. In the fan system of electric fencing the wire is fanned out from two fixed points alternately.

of the more usual 2 cwt. per acre produces a second crop of grass without further fertilising. Early grass must be carefully rationed to the stock because it is precious food, and strip grazing with an electric fencer, allowing $\frac{1}{2}$–$\frac{3}{4}$ acre for 50 cows for a full day's grazing is advocated. The

layout of the fencer will vary with the field and suggestions are given in Figs. 18, 19, 20.

It pays to move the fence twice daily, using the milk yield as a guide to the amount of grass required. Keep wire straight, taut and about 30 in. above ground and the battery in good order. A back fence is advisable if cows are likely to be in the field for more than 3 days.

The average dairy cow should produce 4 gallons milk daily on grass alone for a long part of the grazing season.

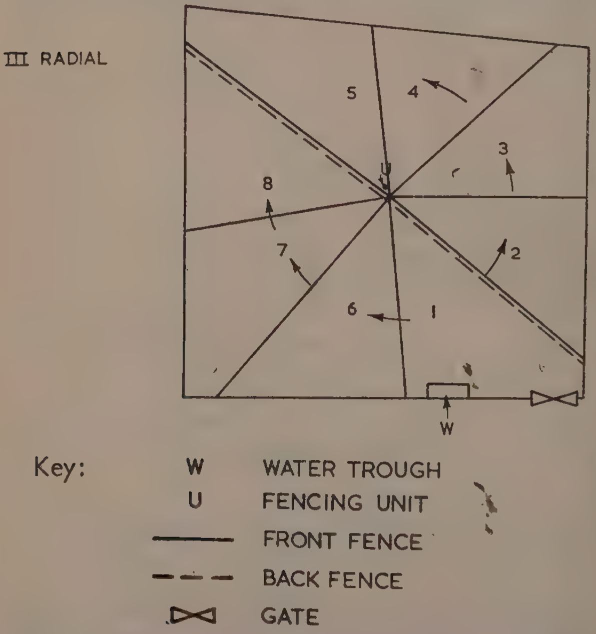


Fig. 20. In an awkwardly shaped field this radial system may be most convenient where the fence is not moved every day.

Many examples could be quoted of yields of 700–800 gallons per cow per season from grass alone.

When first turned out watch must be kept for signs of scouring or bloat. Feeding hay or straw, moving the electric fencer half an hour prior to bringing the cows in to milk, or finally resorting to the use of penicillin have all met with success, depending on circumstances.

HAYMAKING

Haymaking simply involves the reduction of the moisture content of the fresh grass from about 80 per cent. to some 15–20 per cent., drying off the unwanted moisture by harnessing sun and wind. At around 15–20 per cent. moisture content, the material can safely be stored in stacks until such time as it is needed for feeding.

VARYING EFFECTS OF WEATHER

Unfortunately since no control can be exercised over sun and wind, nor on the rain, haymaking is normally a precarious process. During bad weather, the losses in feeding value can be very serious, and even in fine weather appreciable, as shown in the following table of losses in haymaking:—

TABLE 18

Weather	Starch Equivalent per cent.	Protein Equivalent per cent.
Showery	48·4	53·7
Fine	33·0	28·7
Very fine	23·0	17·0
Average	32·0	29·4

These can be regarded, however, as comparatively minor losses, for, should very bad weather persist, it is not unusual to lose the crop completely.

IMPORTANCE OF TIME OF CUTTING

Apart from the weather the final feeding value of the product is influenced by the time of cutting. With increasing age, grasses and clovers decrease in feeding value and once

the flowering stage has been reached, the feeding value rapidly declines, until at the seeding stage it is at a minimum. The feeding value of herbage plants resides in the leaf and not in the stem.

Thus, if the plant is dried to the point of brittleness, as is quite possible when the hot, scorching sun's rays are given full chance to work upon the cut crop, there is a decided danger that the operations of gathering the hay together will break off the leaves, and only the stems will be carted home. Moreover, the action of the sun is to bleach the colour, and since the green colouring of plants is associated with carotene, the precursor of vitamin A, this is seriously reduced, whilst vitamin C disappears completely.

Another invisible loss is due to the effect of heating in the stack. High temperatures reduce the digestibility of the protein in the crop. A slightly browned hay may have lost one-quarter of its feeding value, whilst if the temperature has reached the point where charring has actually taken place, the loss is very much greater.

Finally, the composition of the herbage itself has a direct bearing on the value of the final product. The protein content of clover does not fall so rapidly with advancing age as does that of the grasses. Hence, the more clovery the herbage, the better the value of the hay, and the more latitude one has.

The whole position can be summed up by saying that quality in hay is of paramount importance, and to secure this quality means cutting when the crop is in the young and leafy stage, drying it as expeditiously as possible, and finally storing it under cover, thus ensuring an unbleached, unblemished fodder with a pleasant aroma and withal of high feeding value.

HAYMAKING METHODS

Considerable variations in the methods of making hay exist in Britain between county and county, and the particular method adopted is largely dictated by weather conditions. In the eastern half of England, where the average rainfall is below 30 inches, full mechanisation is possible, and the very essence of the process is speed. On the western side and in the northern counties, where rainfall exceeds 30 inches and

where it is unusual to have long spells of dry weather, the essence of the process must be security, and methods have to be adopted which reduce as far as possible the danger of damage by the weather. Basically, of course, the process is identical no matter where hay is made. The crop is cut into swathes which are left to dry on the upper surface before being turned to allow the under surface to dry out. Finally the material is collected together, drying taking place the whole time, until when the moisture is reduced below 20 per cent., it is safe for carting and stacking. Material improvement in the time taken to cure the herbage can be effected by following the mowing machine with a tedder, the best type being the spring-tine, back-kicking undershot cylindrical machine. In this way the swathes are tossed up and lightened, and air circulates throughout the green material. Under normal weather conditions, teasing out the swathe in this way saves one day's fielding. Crushing, bruising and laceration are also helpful to ensure the stem dries as quickly as the leaf, but these need special machinery and an accurate forecast of the weather.

Green hay with 45 per cent. moisture can safely be put on tripods or racks for final curing, but building the hay on these is an art which must be acquired for successful results.

The most recent development in the process having a direct bearing on the quality of the product is that of baling. With the medium density string or wire tying automatic pick-up baler the moisture content of the hay should not exceed 30 per cent. Such bales should remain stooked in the field for 4–7 days to cure before stacking. Hay up to 40–45 per cent. moisture can be baled, provided it is stacked in small, well-ventilated stacks—the density should be 3–4 lb. per cu. ft. Such bales must not be left out, having little resistance to rain and the method is risky. With pick-up baling the hay must be collected when free of surface water. Straw should be placed 1 ft. deep on top of the stack to absorb condensation water and prevent wastage in the top layer of bales.

Of late, the practice of barn drying has received considerable attention in Britain. After the initial bulk of moisture has been evaporated from the cut crop by natural means leaving around 35–45 per cent., the semi-dried hay is carted to the barn, where the making is completed under cover by

forcing air, either cold or heated, through the mass. Full details of the various methods of drier construction should be obtained from a competent authority after reference to Table 73.

Research work at Jealott's Hill and at Seale-Hayne College has indicated that when hay is top-dressed with a nitrogenous fertiliser, say 2 cwt. nitro-chalk per acre, as late as 10–14 days before cutting the crop, the plant has the capacity for converting the nitrogen into protein, thereby improving the feeding value. Normally, the crude protein of the hay can be increased by 2–3 per cent. in this way, and any nitrogen not utilised by the plant in protein building serves to increase the yield of aftermath. When this practice is adopted in conjunction with earlier cutting and allied to a "safe" harvesting method, the way is cleared for the production of a much higher quality product.

SILAGE

Ensilage—The process of "ensilage" consists of preserving green forage crops in a succulent condition for use later in the season. "Silage" is the product so obtained and a "silo" is the container in which it is made. The latter may be a round or rectangular above-ground structure of wood, concrete or sheet metal or it may be merely a pit dug in the ground or a stack.

Principles of Silage Making—The process is one of fermentation, the carbohydrates within the plant cells being converted by bacteria carried on the plant material into lactic, acetic and butyric acids. In well-made silage lactic acid is dominant constituting from 0·5 to 2 per cent. of the fresh weight of silage. The formation of this acid must be encouraged to keep the organisms producing buytric acid—which is undesirable—in subjection. Respiration within the mass of material packed into the silo is controlled by compaction or treading, the amount necessary varying with the degree of maturity or wetness of the crop and the rate of filling. The temperature should be 80–100° F. and to secure a uniform product, each day's filling should attain this level. The acidity of the mass should be greater than pH 4·5 say pH 4·0 or even less. The only means of controlling the pH is by creating favourable conditions for the rapid production of lactic acid.

Well-made silage is yellowish brown in colour with a pleasantly acid smell of " cheese and pickles." All the plants should retain their leaf formation. The actual feeding value of the silage depends upon the stage of maturity of the crop when cut. Protein in plant tissues is at a maximum at the pre-flowering stage. Thereafter it falls rapidly and is at a minimum when the seed has set. The fall in protein content is not so rapid in leguminous plants as in the grasses and cereals and hence the presence of clover in the grass crop or of tares, peas or beans with a cereal influences the composition of the silage. The ideal is to cut a clovery sward or lucerne when first coming into the bud flower stage or in the case of a cereal-legume mixture, before the ear has shot.

There are four methods of making silage: (i) the ordinary, (ii) the molasses or indirect acidification, (iii) the acidification methods, (iv) controlled bacterial action.

The ordinary method—For this method the crop must be cut when past full flower, say the oat kernels cheesy, the tares podded or in the case of grass, when the pollen has blown. At this stage of development the carbohydrates present in the plant supply all the sugary material necessary for the development of lactic acid. Care must be taken when ensiling such mature material to avoid high temperatures giving rise to a brown sweet-smelling product which, though palatable, is of low feeding value, much of the protein being rendered indigestible.

Molasses method—Crops cut at an immature stage of development are rich in protein but poor in fermentable carbohydrate and when ensiled, therefore, an easily fermentable carbohydrate such as molasses must be added. Sugar beet pulp, potato flakes and molassed meal preparations have been used to replace molasses. The following amounts of molasses are required:—

Young grass—20 lb. (or 1½ gal.) per ton of crop.

Clover, Lucerne, Sainfoin—30–40 lb. (or 2¼ to 3 gal.) per ton of crop.

For moist crops the molasses is dissolved in an equal volume of water. For dry crops it may be mixed with 2–3 times its volume of water.

Acidification methods—The addition of an acid solution direct to the crop to bring the pH level to 3·5 to 4 as rapidly

as possible is the basis of the A.I.V. method, the A.I.V. acid used consisting of a mixture of hydrochloric and sulphuric acids with a small amount of organic acid. In America phosphoric acid has been used successfully whilst on the Continent formic acid has been tried. In practice these methods have drawbacks, the concentrated acid being dangerous to handle and needing to be added with some precision to the herbage. Surplus acid may cause serious scouring in the stock.

Controlled bacterial action—Of recent years the use of sodium metabisulphite (10–12 lb. per ton of green material) has been advocated as a means of limiting bacterial action. To be effective it must be intimately mixed with the green crop—which is best chopped—and the silo must be filled as rapidly and evenly as possible. Success depends on complete exclusion of air. Further evidence is necessary before the method can be generally recommended.

More recently machines of various types have been used which have a lacerating action on the plant tissues and in liberating the starchy material within, it is claimed, the addition of molasses or acid is unnecessary.

The use of salt has sometimes been advocated. In the concentrations applied it is not a stimulant for bacterial activity nor can it act as a bactericide and hence it is likely that equally good results would be obtained without using salt.

The process of ensilage is wholly preservative and not creative and the value of the final product is determined primarily by the quality of the material ensiled.

Crops for Ensilage—Most herbaceous crops can be made into silage together with by-products from arable farming such as potatoes, sugar beet and mangold tops. Apples also may be made into silage.

Grass—The quality of the silage produced from grass depends upon the age of the material when cut. The younger and leafier the richer in protein. Grass land generously fertilised yields on the average 4 tons of fresh grass per cut per acre or three tons of finished silage. Clover, lucerne, sainfoin are comparable with young grass in producing high-quality silage but yield about 25 per cent. more weight per acre. The fall in protein with advancing age is

not so marked in legumes as in the case of grasses, hence the value of including them in seed mixtures for ensiling. These plants all require the addition of molasses when cut at the pre-flowering stage.

Arable Silage Crops—Oats and tares constitute the most common silage mixture used in this country. In the south the crop is usually sown in the autumn using winter hardy varieties; in the north it is more common to rely on spring varieties. Peas may be included in mixtures for spring sowing and beans for autumn-sown crops. Beans should be ploughed in a fortnight before the cereal components in a mixture. Rye is a very reliable crop but needs to be ensiled before the ear shoots.

The following mixtures are recommended:—

Average Soils	lb. per acre	Light Soils	lb. per acre	Heavy Soils	lb. per acre
Oats	140	Oats ...	140	Oats ...	112
Tares or Peas ...	56	Tares ...	28	Beans ...	56
		Peas ...	28	Tares ...	56
Rye	112	Rye ...	112		
Winter vetches	42	Rape ...	4		
Italian ryegrass	20				

With all cereal-legume mixtures it is useful to sow 10–20 lb. Italian ryegrass to provide keep when the silage crop has been removed.

Cereal-legume mixtures are usually cut when the oats are in the milky stage. Molasses is not required and the silage must be regarded as a medium quality fodder.

Grass and Clover Mixtures—On good land the following mixture has given 8–9 tons of silage per acre per season in three cuts:—

	lb. per acre
Ryegrass H.I. (short rotation)	30
S.100 White Clover	4

as also:—

Italian ryegrass	6
Broad Red Clover	8
White Clover S.100	2
Trefoil	2

On land where lucerne is known to do well the following mixture should be tried:—

	lb. per acre
Cocksfoot	3
Lucerne	20

Maize—Maize is grown extensively in the U.S.A. for ensiling, but in this country it is confined to the drier and warmer districts of the south and south-east. The crop is cut in September when the grain is soft and pasty. No molasses is required. Early maturing varieties like Compton's Early, Eureka, and Early Leeming are now recommended although the older White Horsetooth gives a very good yield. The sowing of maize must be delayed until all danger of frost is over.

Kale—The best method is to use a clamp, the kale, which must be chopped, being formed into a large heap without treading or the addition of molasses. The clamp does not require earthing down for a thin layer of mould forms on the outside which makes a perfect seal. Rain should be kept out by covering over with straw. About one-third of the dry matter of the crop is lost in fermentation and drainage, but when yields of 30 tons per acre or more can be obtained the crop is worth growing specifically for silage especially as the protein content is likely to place the silage in the cake-substitute class.

Rape and cabbage can be made into good silage if care is taken to ensure that the mass attains 90° F. Some difficulty may be experienced in chopping well-hearted cabbages.

By-product Silage Crops—Beet tops should be kept free from soil and must be ensiled in a fresh condition. For small quantities a container may be used but for large quantities the pit is by far the best type of silo, using the tractor for consolidation. It is advisable to make sure the mass attains 90° F. but no molasses is needed.

Mangold tops can be dealt with in a comparable way. The yield is not so great, lacking the crown of the beet, nor is the feeding value of the final product so good.

Potatoes make excellent silage but are best steamed for the purpose. They can be packed straight from the steamer—

after allowing any condensed steam to drain away—in a pit of suitable dimensions. Alternatively a tower silo can be used if suitably strengthened. There is no need to add molasses or watch the temperature and filling can be continuous.

A simpler method for dealing with surplus potatoes in the late spring or early autumn is to place alternate layers of grass (12 in.) and uncooked potatoes (6 in.) in a silo. The heat developed by the grass will partially cook the tubers. If a suitable building exists the potatoes can be steamed *in situ* by leading the steam direct into the container which must of course be airtight.

Pea haulms and pods—Pea haulms should be kept free from soil and ensiled in as fresh condition as possible. Molasses is not required. Pea pods make excellent silage; no molasses or treading is required but provision must be made for the collection of a considerable quantity of effluent. Over treading must be avoided.

Apple pomace and Brewer's grains can be ensiled successfully. Apple pomace is rich in carbohydrate and needs no molasses. Fresh brewer's grains mould rapidly and the ensiling must be expeditious.

Above ground silos may need strengthening for both these materials.

Apples—Surplus apples can be ensiled after steaming in the same manner as potatoes.

SILOS

Tower, pit, clamp and stack silos are available, the type chosen being selected to fit in with farm needs. Siting the silo with reference to the availability of the crop and the access for feeding is very important. In calculating size of silo required allow 2 cubic yards per ton of made silage and aim to produce 3 tons of silage per cow.

The tower silo gives the most satisfactory result, but is expensive and inelastic; the stack is cheap and elastic but much waste is incurred and to-day the clamp or pit or clamp-cum-pit methods are usually adopted. The ideal width for a clamp is 20 ft., the minimum width 14 ft., and a minimum settled height of 5 ft. of silage is essential. To keep out rainwater both during and after filling, therefore securing

a silage of high dry matter, a roof is highly desirable. Hence the modern tendency to site a clamp silo under a dutch barn. Where self-feeding is intended a hard floor is necessary, a minimum of 9 in. of silo face per cow (dehorned) allowed, and the floor slope in such a fashion that urine and dung seep away from the silage face. The ideal layout for this purpose is undoubtedly the clamp sited under a dutch barn.

HANDLING THE CROP

For grass, clover, lucerne and other comparable crops the ordinary mowing machine is quite satisfactory for cutting. An inner swathboard is necessary when the grass is to be baled direct. For short hauls (up to half a mile) the buckrake either rear-mounted or fitted on to a front-end loader is the quickest and cheapest method of collection. The buckrake picks up two mower swaths, working in the same direction as the mower, and carries from 4 to 8 cwt. of crop. A buckrake mounted on a hydraulically operated front-end loader can be used for filling trailers and waggons where longer distances are involved. Generally, where trailers are used the green crop loader is the best machine. With a self-emptying trailer this constitutes a one-man outfit. Forage harvesters which cut, chop and load the material are also available. High-sided trailers are desirable, and with a fairly heavy tractor outputs of up to 8 tons per hour can be achieved.

The pick-up baler can also be used. Half-size bales (about 60 lb.) are needed and the cost of twine, therefore, offsets some of the advantages of handleability. Low loading trailers or sledges facilitate work in the field. For short hauls the buckrake can be used.

In filling the silo it is well to remember that each 3–4-ft. layer of crop should attain 90° F. before adding more. A silage thermometer should be purchased. Uniform filling and consolidation produces a uniform silage. Wilting for 12 hours in the field promotes fermentation and it is often a good plan to commence filling a silo on a Friday to allow the material to heat up over the week-end. Chopped material requires less consolidation than unchopped. If bales are used they should be packed as tightly as possible, strings on top, and should not be bonded. Each layer must

be thoroughly consolidated. Much greater care is necessary with this method than with loose material if a uniform silage of high feeding value is to be secured. Finally the silo should be sealed to add weight to the topmost layers and keep out air. A roof, either temporary or permanent, as indicated earlier on, is desirable and pays for itself in a few years. It is a good plan to top up with waste grass or other material, which should be well consolidated before the final seal of soil is laid on. Some 6–12 in. of soil well rammed into position makes the perfect seal, giving the desired consolidation to the upper layers of silage as well as sealing off from the air.

The cost of getting the soil into position is expensive of labour and an increasing number of farmers now omit this sealing, merely stripping off the layer of mouldy material which forms on the exposed surface of the silage and contending that this is cheaper than soiling down. Especially is this true of pit silos where a large upper surface is exposed. Where waste material is available for topping up the omission of the soil seal is not serious, but it must be remembered that greater care is then necessary to secure consolidation in the upper layers of the silo. Ground limestone, either loose or in bags, is often used.

Causes of Waste in Silos—Side waste—usually consisting of black slimy material varying in thickness from a few inches to as much as a foot along the wall of the silo. The cause is entry of air through the walls of the silo and also from the seepage of rainwater into the silo.

Mouldy Patches in any part of a silo are caused by air pockets. Failure to shake up the material in the silo, uneven treading or consolidation are the usual causes. Once a silo is opened the silage will soon mould and should be used fresh daily or at most every other day.

Pungent, Evil Smelling Silage—The smell is usually one of rancid butter, is very clinging and is often associated with very wet silage of an olive green colour. This is caused by a butyric fermentation resulting from too low a temperature —less than 80° F.—and is usually brought about by ensiling very immature, wet material and failing to allow the mass to attain 90° F. in each three-foot layer of material added before continuing filling.

TABLE 19

CLASSIFICATION OF SILAGE

(Grade 1) (High Quality) Cake Substitute (15% and over crude protein)	(Grade 2) (Intermediate Quality) Hay and some Cake, or Hay Substitute (12 to 14·9% crude protein)	(Grade 3) (Low Quality) Hay, Roots or Straw Substitute (Less than 12% crude protein)
Young grass—no grasses in flower Clover, lucerne, or sainfoin in bud stage Mid-season grass heavily fertilised with nitrogen or grazed late	Grasses at flowering stage Late autumn grass Clover passed full flower Cereal-legume crops cut when cereal is "milky" Marrow stem kale Pea pods	Grasses at seeding stage Stemmy, mature clover Maize Pea haulms and pods Sugar beet tops Potatoes Mangold and turnip tops

Feeding of Silage—Silage can be used for maintenance or production requirements of livestock depending upon its quality. No hard and fast rules can be laid down as to the amounts to be fed to the various classes of stock, and farmers using silage for the first time are urged in their own interests to seek expert help and guidance.

Response of milk cows to silage is very marked and, as it is important to maintain the milk supply, cows in milk should have first call on the silage available and should receive the best that has been made. All dairy farmers experience the difficulty of maintaining yields in March and April, when the cows begin to tire of winter rations and the spring grass is still insufficient to justify turning out.

Those who have silage, however, will find that it bridges this gap, and that by its use in the hungry months of the year milk yields can be maintained. By utilising silage to the fullest extent in the feeding of cows giving up to three gallons of milk, the very expensive cakes and meals now available can be reserved for the high-yielding cows. An amount of six pounds of good molassed grass silage replaces one pound of balanced dairy ration.

Silage is also a valuable food for fattening cattle, and high-quality silage replaces the cake normally fed to this class of

animal. To feed a large quantity of this type of silage, however, may be wasteful by providing more protein than the animal requires. Thus the intermediate quality silage may be more useful to replace hay, straw or roots, for fattening cattle.

Recent work in Northern Ireland has shown that good grass silage can be fed alone as a fattening ration for bullocks. Up to 126 lb. per head per day was fed for 10 weeks during which period the average liveweight increase per day was 2·8 lb., the killing out percentage being 60.

As a general rule, however, dairy and fattening stock will receive amounts of 35–60 lb. per head per day, along with other foods.

Store cattle are likely to winter well on a ration of 20 to 30 lb. of silage (Grade 2 or 3) in addition to hay, and calves should have it introduced into the ration at an early age to replace part of the roots and meal.

It is not generally realised how useful silage is for ewes in lamb and for fattening wethers. It should be introduced to them gradually by feeding about one lb. per head per day, preferably of good quality silage made from short grass. Results over a number of years show that a ration of 10 to 12 lb. silage with 6 lb. good hay and one lb. crushed oats is likely to give a liveweight gain of two to three lb. per sheep per week. Compared with feeding roots silage will show appreciably lower costs of production and in labour of feeding.

There is no reason why the sole diet should not be good grass silage and in one recorded case in Northumberland over a period of two years feeding lambs weighing 124 lb. liveweight had grass silage alone from December until sold fat (67–69 lb. deadweight) some five to six weeks later.

Ewes do especially well when silage forms at least part of the diet. They lamb easily, milk well and are markedly healthier under adverse weather conditions whilst their lambs are noticeably superior to those running with ewes receiving no silage. In one particular trial in Yorkshire ewes which received 5 lb. of good grass silage per head per day from three weeks prior to lambing until weaning time showed 10 per cent. less mortality amongst the lambs which averaged 5 lb. per head heavier when weaned compared with lambs from comparable ewes which did not, however, receive any silage during the comparable period. With all sheep care

must be taken not to feed any doubtful silage. It can be thrown out on to grass or given in racks, but it must be protected from wet or it becomes slimy and refused by the sheep and hence racks are to be preferred.

Silage is much too bulky a feed to play any considerable part in the feeding of pigs or horses, as both classes of stock have comparatively small digestive organs. Pigs can receive up to 2 lb. daily as a tonic and supplier of vitamins, lack of which is often responsible for many pigs failing to thrive. Empty sows can receive as much as 15 lb. and this replaces 3 lb. of pig meal. The silage fed to pigs will largely be of the by-product type. Potato silage is particularly useful for pigs, replacing steamed potatoes.

Although silage is seldom fed to horses, brood mares benefit from a few pounds daily of molassed grass silage during the winter, whilst up to 25 lb. per day can be fed to working horses without fear of ill effects.

At a time when concentrated foods are extremely expensive the introduction of silage into poultry rations deserves attention. Little information is available as to its use in this country, but American and Continental experience is fairly extensive and has shown that when the silage is chopped and mixed with meal to a crumb-like consistency, up to 2 oz. per bird per day can be consumed, and the quantity of laying meal required reduced by as much as 25 per cent. Usually, when small quantities of silage for poultry are required it can best be made in barrels holding about 3 cwt. Lawn clippings are ideal for this purpose. Steamed potato silage is equally valuable.

GRASS DRYING

Artificial Drying—When grass, clover or lucerne is dried by artificial means there is little loss in feeding value and the product is rich in protein. The dried material is easily stored, transported and simple to ration and, in this respect superior to silage. For pigs and poultry it is the only convenient protein-rich concentrate which can be obtained from grassland. Dried grass is a valuable food because it contains a large range of vitamins, easily digested minerals and the full range of the proteins required by farm animals. It makes other foods go farther by supplementing the insufficient range of proteins available in cereals and seed crops.

High-quality grass for drying is grown by fertilising good permanent or temporary leys with nitrogen, phosphates and potash, e.g., 3 cwt. of superphosphate, 1 cwt. of muriate of potash and 6–12 cwt. of ammonium sulphate or Nitro-chalk per acre. The nitrogen can be applied in the spring at 4 cwt. per acre and the rest at intervals later in the season. Three, four or five cuts of grass are made during the summer. The approximate yield obtainable and the quality of the dried grass is given in the following table, the crude protein content being the average of all the cuts made during the summer.

TABLE 20: RELATIONSHIP BETWEEN FERTILISING, CRUDE PROTEIN AND YIELD OF GRASS

Total weight of Nitro-chalk applied per acre	Crude protein in dried grass; average of all cuts	Total weight of dried grass; all cuts from 1 acre
cwt.	per cent.	cwt.
0	11	35
6	16	50
12	18	60
15	20	70

Cutting and Collecting—The grass is usually cut with an ordinary hay mower and first wilted in the field for one to two days to remove some of the water content. Less drying is then necessary at the drying plant. The swathe is either picked up by hand-loading into carts or trailers or with a buckrake on a tractor or with a green crop loader. Machines to cut and deliver the grass into a trailer which carries it in the unwilted state to the drier are available.

Lucerne does not require nitrogenous fertilisers but if lucerne-grass mixtures are grown nitrogenous fertilisers must be applied or the protein content of some of the cuts will be low.

Driers—In all driers hot air is used to remove water from the grass, the air being heated by burning coke or oil although coal or electricity is sometimes used.

Some grain driers are capable of simple conversion for use as grass driers, thus making them especially suitable for the small farm where costly plant would not be justified. Any farmer who contemplates grass drying should seek specialised information concerning the latest equipment.

Storage of Dried Grass—Dried grass does not pack like hay, being very springy. When trodden down it only packs to about 6 lb. per cubic foot. It can be made into chaff one to two inches long, and trodden down in chaff rooms when it packs to about 12 lb. per cubic foot. It may be made into bales weighing 80 to 90 lb. with an ordinary straw baler or a small baler may be used for making bales 30 to 40 lb. The density in bales varies from 12 to 20 lb. per cubic foot, but bales of about 12 to 14 lb. per cubic foot require less power and are quite satisfactory. Dried lucerne is too brittle to make into bales. Grass or lucerne may be ground to a meal in a hammer mill and kept in bags, the density of which is about 24 lb. per cubic foot. Meal is best for storage and transport and for feeding to poultry or pigs, but bales are the most convenient form for feeding to cattle. If dried grass, packed in paper bags, is stacked about 6 ft. high one ton occupies two square yards of floor space.

Dried Grass Analyses—The feeding value of dried grass or lucerne is related to the crude protein content, and farmers drying crops should have their product analysed for crude protein weekly by the National Agricultural Advisory Service or by Agricultural Analysts. Sampling should be done carefully—a handful of meal being taken from every fifth bag and put into a closed box. At the end of the week this must be well mixed and about half a pound sent for analysis. Bales should be sampled by boring a hole through about one bale in ten—mixing the samples obtained in a closed box and then carefully making an average sample from the contents of the box. It is very difficult to get an average sample from the grass before it is baled for the leaves, which are brittle, break up and too little leaf matter is therefore included in the sample which is then too low in crude protein.

The fibre content of dried grass varies from 20 to 30 per cent. Since cattle and other ruminants digest a large proportion of the fibre the content of fibre is of little moment

for them. But for feeding pigs and especially poultry it is advisable to select dried grass which is low in fibre. High protein dried lucerne often contains only 15–18 per cent. of fibre. This is particularly valuable for poultry mashes. Dried cabbages, kale leaf and similar crops often have low fibre contents.

The beta carotene content of dried grass, which is a measure of the vitamin A potency, usually varies between 200 and 400 milligrams per kilo and for lucerne between 100 and 300 milligrams. When dried grass or lucerne is included in a ration to provide starch equivalent and protein the animal receives all the beta carotene required if the carotene content is over 80 milligrams per kilo. Although dried grass loses beta carotene gradually on storage any sample which contained more than 100 milligrams per kilo at the time of manufacture will still provide all the carotene that an animal requires. On the other hand, if small quantities of dried grass are added to a ration for the sole purpose of supplying vitamin A a high carotene sample is preferred because less of it will be required.

The following are typical analyses of dried grass and lucerne:—

TABLE 21: SPECIMEN ANALYSES OF DRIED GRASS AND LUCERNE

DRIED GRASS

	Per cent. of the dry matter			
Crude Protein	10·86	14·55	16·36	19·09
Fibre	28·2	25·38	26·00	24·80
Beta Carotene milligrams per kilo	Varies from 200 to 400			

DRIED LUCERNE

Crude Protein ...	16·43	18·2	20·62	22·56	23·93
Fibre	26·35	23·4	17·45	15·45	15·65
Beta Carotene milligrams per kilo...	150	210	205	210	275

Under the Ministry of Agriculture scheme for the grading and marking of dried green crops the grade is determined by the per cent. of crude protein when the moisture content is 10 per cent.

Cattle—Dried grass or lucerne will be used as a replacement for protein-rich foods in the rationing of cattle, except low grades which then take the place of hay. The following table shows the relationship between crude protein content and feeding value and gives the average requirements for cattle of varying ages.

TABLE 22

Weight (lb.) of dried grass containing 10 per cent. moisture to be fed to cattle.

			per cent.		
Crude Protein in dried grass.	10–11	12–13	14–15	16–17	18
(*a*) Starch Equivalent	51	52	53	54	55
Protein Equivalent	5·5	7·5	9·5	11·3	12·7
(*b*) Daily ration for young stock—					
Weight of animal	lb.	lb.	lb.	lb.	lb.
2 cwt.	—	—	—	6	6
4 ,,	—	—	8½	8	8
6 ,,	—	—	10½	10½	10
8 ,,	—	13	13	12½	12½
(*c*) Daily ration for fattening cattle for 1½ to 2 lb. live weight increase per day—					
Weight of animal					
6 cwt.	—	18	18	17	17
7 ,,	20	20	19	19	18
8 ,,	21	21	20	20	20
9 ,,	23	22	22	21	21
10 ,,	24	23	23	22	22
Plus oat or barley straw.					
(*d*) Dairy Cows (1000 lb. live weight)—					
Maintenance ...	12	11½	11½	11	11
,, and 1 gal.	—	16½	16	16	15½
,, ,, 2 ,,	—	21	21	20½	20
,, ,, 3 ,,	—	—	25½	25	24½
,, ,, 4 ,,	—	—	30	29½	29

(*a*) The starch equivalent and protein equivalent corresponding to the various crude protein contents.
(*b*) The daily ration for young cattle necessary for maintenance and for an increase in live weight for normal growth of about 1 lb. per day. Calves will start eating dried grass when three weeks old, and at 2 to 3 months they will eat about 4 lb. per day.
(*c*) The daily ration for fattening cattle to produce about 2 lb. live weight increase per day. The cattle should have access to oat or barley straw so that they can satisfy their appetites after they have consumed the dried grass.
(*d*) The daily ration for cows which should be varied according to breed.

Dried lucerne—Dried lucerne contains more protein equivalent and less starch equivalent than dried grass so that it requires mixing with a starchy food such as oats, barley, or maize in making up a milk production ration for cows. The amount of dried lucerne to be mixed with a starchy food to

TABLE 23: MEAL MIXTURES WITH LUCERNE

Crude Protein in lucerne meal containing 10 per cent. moisture, per cent....		16	18	20	22	24
Starch Equivalent, per cent.		43	45	47	49	51
Protein Equivalent, per cent.		11	13	14½	16	18
lb. of lucerne meal to be mixed with a starchy food		90	52	40	31	26
lb. of starchy food to be mixed with lucerne meal. (quantities above)		Weight of mixture in lb. to be fed for 1 gallon of milk to cows averaging about 1000 lb. live weight.				
	lb.					
Barley...	30	5½	4½	4½	4¼	4¼
or Linseed	40	4	3¼	3	2¾	2¾
or Maize	25	5½	4¼	4¼	4	4
or Maize Germ Meal	30	5	4	4	3¾	3¾
or Oats	45	5½	4½	4½	4½	4¼
or Rye	40	5¼	4½	4¼	4¼	4
or Sugar Beet pulp	30	6	4¾	4¾	4¾	4½
or Wheat	40	5¼	4½	4¼	4¼	4

make a balanced milk production ration depends upon the quality of the dried lucerne. Table 23 gives the starch equivalent and the protein equivalent of dried lucerne from 16 to 24 per cent. crude protein content and the weight of each quality to be mixed with given weights of some common starchy foods.

Guernsey cows require one-fifth more than the above quantities and Jersey cows one-third more.

EXAMPLE—40 lb. lucerne meal (20 per cent. crude protein) and 45 lb. of oats are mixed to make a milk production ration and $4\frac{1}{2}$ lb. are fed for each gallon.

Pigs—Dried grass or lucerne can replace the weatings in a ration for in-pig sows, suckling sows and fattening pigs. The amount fed can be 30 per cent. of the total food. On account of its vitamins and minerals it enables sows to rear large litters.

Poultry—All poultry mashes should contain 7–10 per cent. of high protein dried grass or lucerne meal. This is particularly important in the case of birds kept in batteries for it provides vitamin A, vitamin B, some useful minerals and proteins, and ensures that the yolks of the eggs will be of a good colour and not white.

FRUIT, VEGETABLES, GLASSHOUSE CROPS

Apples (dessert) in Order of Maturing

Early (Aug.–Sept.)—*Beauty of Bath, Laxton's Epicure.

Mid-Season (Sept.–Oct.)—*Worcester Pearmain, Ellison's Orange, *James Grieve, Laxton's Fortune, Lord Lambourne.

Late (Oct.–Nov.)—*Cox's Orange Pippin, *Blenheim Orange, Allington Pippin, Laxton's Superb, Sunset.

Very Late (Nov.–Jan.)—Winston, Wagener, Sturmer Pippin.

Apples (cooking) Order of Maturing

Early (July–Aug.)—Emneth Early (syn. Early Victoria).

Mid-Season (Aug.–Oct.)—Grenadier, Lord Derby.

Late (Oct.–Jan.)—*Bramley's Seedling, *Lane's Prince Albert, Monarch.

Very Late (Dec.–Mar.)—*Newton Wonder, *Crawley Beauty, Edward VII.

NOTE—Some apples are self-incompatible; some only partly self-compatible; others have bad pollen. Those marked above * should always be planted with *suitable* pollinating varieties. All apples are better for cross-pollination.

Pears (in order of Maturing)

Early (Aug.–Sept.)—Laxton's Superb, William's Bon Chrêtien.

Mid-Season (Oct.–Nov.)—Dr. Jules Guyot, Beurré D'Amanlis, Fertility, Emile D'Heyst, Conference.

Late (November)—Durondeau, Beurré Hardy, Doyenné du Comice.

NOTE—Most varieties of pears require cross-pollination to ensure adequate crops and should be planted with *suitable reciprocal pollinators.*

Plums (in Order of Maturing)

End July onwards—*Early Laxton, *Rivers's Early Prolific, Cherry Plum (Myrobalan), Czar, *Cambridge

Gage, Victoria, Denniston's Superb, Oullins Golden Gage, Belle de Louvain, *Jefferson, *Bryanston Gage, *Pond's Seedling, Giant Prune, Warwickshire Drooper, *Kirke's Blue, Marjorie's Seedling, Blaisdon Red, Kentish Bush, Monarch, *President.

NOTE—Some plums are self-incompatible and others only partly self-compatible. Those marked above * should always be planted with suitable pollinating varieties.

Cherries (in order of Maturing)

Early—May Duke (June), Early Amber, Early Rivers, Frogmore, Knight's Early Black, Nutberry Black, Governor Wood.

Mid-Season—Amber Heart, Roundel Heart, Waterloo.

Late—Emperor Francis, Napoleon, Gaucher, Noble, Bradbourne Black, Noir De Guben, Turkey Heart, Geant D'Hedelfingen, Florence, Ohio Beauty (August).

NOTE—All sweet cherries are self-incompatible. Also cross-incompatibility exists. Each of the above varieties must therefore be grown with a *suitable* pollinating variety *which is reciprocal.*

Blackcurrants (in Order of Maturing)

Boskoop Giant, Mendip Cross, Davison's Eight, Goliath, French Black (Seabrook's Black), Wellington XXX, Westwick Triumph, Baldwin, Cotswold Cross, Westwick Choice, Daniel's September.

NOTE—Blackcurrants are attacked by the "reversion" virus; healthy stock only should be planted. Officially certified stocks are available in quantity.

Red Currants (in Order of Maturing)

Earliest of Fourlands, Laxton's No. 1, Fay's Prolific, Laxton's Perfection, Wilson's Longbunch.

Gooseberries (in Order of Maturing)

May Duke, Keepsake, Careless, Lancashire Lad, Whinham's Industry, White Lion, Early Sulphur, Leveller.

NOTE—The last two varieties are especially suitable for dessert fruit.

Raspberries

Lloyd George, Malling Enterprise, Malling Landmark, Malling Promise, Newburgh, Norfolk Giant, St. Walfried.

NOTE—Raspberries are attacked by virus diseases; healthy stock only should be planted. Officially certified stocks are available.

Rootstocks for Fruit Trees

Rootstock affects both the *size* of tree and the crop-yield phase. Stock-scion incompatibility exists with plums and pears and is overcome (in some instances) by double-working (pears). With plums, a suitable single rootstock should be used.

Apples—M.VIII—French Paradise, dwarfing, very early fruiting. M.IX—Jaune de Metz, dwarfing, very early fruiting. M.VII—Semi-dwarfing, early fruiting. M.I—English Broadleaf, semi-vigorous, fairly early fruiting. M.II—Doucin semi-vigorous, fairly early fruiting M.V—Doucin Amélioré, semi-vigorous, fairly early fruiting. M.VI—Nonsuch, semi-vigorous, fairly early fruiting. M.IV—Holstein Doucin, semi-vigorous, fairly early fruiting. M.XIII—Vigorous, fruiting delayed. M.XII—Vigorous, fruiting delayed. M.XVI—Ketziner Ideal, very vigorous, fruiting much delayed. M.Crab C.—Very vigorous, fruiting much delayed.

Pears—Seedling Pear—Large vigorous trees, cropping delayed. Quince A—Moderately vigorous trees, cropping early. Quince B—Moderately vigorous trees, cropping early. Quince C—Dwarfing, cropping very early.

NOTE—Certain varieties of pears are stock-scion incompatible; these should be *double-worked*, using an intermediate variety as a stock-scion compatible union.

Plums—Myrobalan B—Gives large and vigorous trees, fruiting delayed, not suitable for gage plums. Brompton—Gives large healthy trees. Marianna—Medium to large trees, not suitable for *Czar*, *President*, *Oullins Golden Gage* and damsons. Common Mussel—Medium to small trees. Pershore—Small trees, Common Plum—Medium trees, not suitable for *Czar*, *President* and damsons. St. Julien A—Medium trees. Damas C—Medium to strong trees.

NOTE—Certain rootstocks are stock-scion incompatible,

e.g., *Czar* on Common Plum. Certain local plums, e.g., *Pershore*, are commonly grown on their own roots.

CHERRIES (Sweet and Acid)—Sweet Cherry (Mazzard, Gean, Gaskin), M.12/1. Large trees of sweet cherry. Acid cherry small to medium trees.

Peaches and Nectarines

Peach Seedlings—Large vigorous trees. Plum rootstocks —Brompton, Damas C, Common Mussel—Large to medium trees. St. Julian A—Medium to small trees.

Apricots

Plum rootstocks, Brompton and Common Mussel for large trees.

Planting Tables for various Fruits

TREE FRUITS—(Apples, Pears, Plums, Cherries)

Distance in feet.	*No. of trees per acre.*
7×2	3,000 cordons (apples)
7×2½	2,500 ,, ,,
6×3	2,300 dwarf pyramids (apples)
7×3	2,074 ,, ,, ,,
8×4	1,360 ,, ,, ,,
9×9	537 small bushes (apples)
10×10	435 ,, ,, ,,
11×11	360 ,, ,, ,,
12×12	302 ,, ,, ,,
13×13	257 medium bushes (apples, pears, plums)
14×14	222 ,, ,, ,,
15×15	193 ,, ,, ,,
16×16	170 ,, ,, ,,
17×17	150 ,, ,, ,,
18×18	134 ,, ,, ,,
20×20	109 large bushes and half standards (apples, pears, plums)
22×22	90 ,, ,, ,,
24×24	75 ,, ,, ,,
28×28	56 standards (apples, cherries)
30×30	48 ,, ,, ,,
35×35	35 ,, ,, ,,
40×40	27 ,, ,, ,,

NOTE—The previous figures are for square planting. For hexagonal or triangular planting the number given for square planting should be divided by 0·866. *Example*: 10 ft. hexagonal:—

$$\frac{4{,}840 \times 9}{10 \times 10 \times 0{\cdot}866} = 503$$

BUSH FRUITS

Currants and Gooseberries: *Distance in feet.*	*No. of bushes per acre.*	Raspberries: *Distance*	*No. of canes per acre.*	Strawberries: *Distance.*	*No. of plants per acre.*
10 × 3	1,452	5 ft. × 18 in.	5,804	2 ft. × 18 in.	14,520
8 × 4	1,361	6 ft. × 18 in.	4,600	2½ ft. × 18 in.	11,616
4½ × 4½	2,151	7 ft. × 18 in.	4,148	3 ft. × 18 in.	9,680
5 × 5	1,742				
6 × 6	1,210				
7 × 7	888				
8 × 8	680				

BUSHEL AND SIEVE WEIGHTS OF FRUITS

Apples—bushel	=	40 lb.
Pears—bushel	=	48 lb.
Cherries—sieve	=	48 lb.
Cherries—half-sieve	=	24 lb.
Plums—sieve	=	56 lb.
Plums—half-sieve	=	28 lb.

PLANTING

May be done between the middle of October and end of February, but November is the best month. A hole, 3 ft. wide and 1 ft. deep, should be dug for each tree, and the subsoil broken up, and some time before planting, so as to aerate the soil. A stake is driven in, six in. of soil replaced, the young tree tied to the stake, the roots spread evenly, and the soil filled in, and trodden firmly down. The surface should be kept cultivated for several years afterwards, as grass is very harmful to young trees. Not more than six per tree of the larger fruits—such as apples—should be allowed to ripen during the first season.

Some varieties are self-incompatible and some are good pollinators. At least one tree of good pollinating power must be planted to every ten.

Fruit trees respond best to potash manures but some nitrogen is also required: stable manure tends to promote

growth of tree. A suitable dressing of potash is two to four cwt. sulphate of potash per acre. Nitrogen should be applied regularly at the rate of three to four cwt. sulphate of ammonia or five cwt. nitrate of lime (Nitro-chalk) per acre per annum.

CONTROL OF FRUIT PESTS BY GREASE BANDING

Strips of grease-proof paper, eight in. wide, tied round stems at over three feet from ground, and grease compound smeared on these. With older trees the grease can be placed direct on the bark of the stem. Best time is in beginning of October. Object is to check the upward passage of the wingless females of the winter moths.

CONTROL OF FRUIT PESTS AND DISEASES BY SPRAYING

Although these programmes are generally suitable for the small grower it must be remembered that for commercial growers a wide range of materials and formulations is available, resulting in a large number of spray programmes, depending on variety of tree and the pest and disease complex. The product label should always be consulted, and the manufacturer's advice sought if in any doubt.

Materials—Tar oil, petroleum oil, DNC, DDT, BHC, combined BHC/DDT, derris, nicotine, malathion, methyl-demeton, endrin, chlorfenson (CPCBS), chlorbenside, arsenate of lead, lime sulphur, wettable sulphur, captan, thiram, zineb, organo-mercury fungicides, Bordeaux mixture, copper preparations. Most of these materials are manufactured as proprietaries. Follow makers' instructions. The diluent with all liquid sprays is water, plus a suitable spreading agent (spreader) when necessary.

In the following tables the most widely used active substances or formulations are mentioned for each insecticide or fungicide. In many cases, to meet special needs, suitable alternatives are available.

APPLES

Prevalent pests and diseases—Aphids, sucker, capsid, sawfly, codling moth, red spider mite, caterpillars (various), woolly aphid, scab, mildew.

TABLE 24: SPRAYING PROGRAMME

Time of spraying.	Materials.	Pests and diseases controlled.
Mid-Feb. to Breaking Stage	DNC/petroleum	Eggs of aphids, sucker, red spider mite, caterpillar
Burst Stage (early April)	Lime sulphur	Scab, mildew
	or captan	Scab
	BHC or DDT	Aphids, caterpillar
Green Bud (mid-April)	Lime sulphur	Scab, mildew
	or captan	Scab
	DDT	Aphids, caterpillar capsid
	BHC	Aphids, caterpillar
Pink Bud (late April)	Lime sulphur	Scab, mildew
	or captan	Scab
Full Bloom (mid-May)	Wettable sulphur	Scab, mildew
	or captan	Scab
Petal Fall (late May)	Lime sulphur	Scab, mildew
	or captan	Scab
	BHC or methyl-demeton	Sawfly
	Chlorfenson or chlorbenside or methyl-demeton	Red spider mite*
Early Fruitlet (early June)	Lime sulphur	Scab, mildew
	or captan	Scab
Fruitlet	Wettable sulphur	Scab, mildew
	or captan	Scab
	DDT or Lead arsenate	Codling moth
	Chlorfenson or chlorbenside	Red spider mite

* Experience in 1957 indicates that chlorfenson or chlorbenside is best applied in early June, rather than at petal fall.

NOTES

1. *Scab*—Scab sprays should be applied at intervals not exceeding 14 days. Bud stages are given as a guide for the inclusion of insecticides.

Captan is particularly suitable for high-class dessert apples such as Cox's Orange Pippin. It does not, however, control apple mildew.

2. *Spring Sprays*—Sprays containing both BHC and DDT or endrin may be used in place of winter washes to control aphids, caterpillar, sucker and capsid. They may be incorporated with the scab spray applied at the burst stage.

3. *Low Volume Spraying*—Several machines have been developed for applying sprays to fruit trees at reduced volumes. Air is used in place of water as a carrier for the spray chemical. The rate of application may vary from 75 gallons down to 3 gallons of spray per acre and the concentration of active material is correspondingly increased.

4. *Sulphur-shy Varieties*—Some varieties of apples will not tolerate lime sulphur after blossoming. These may be sprayed with captan or other suitable fungicides.

PEARS

Prevalent pests and diseases—Aphids, caterpillars, codling moth, sucker, scab.

TABLE 25: SPRAYING PROGRAMME

Time of spraying	Material	Pests and diseases controlled
Dormant Stage (Dec.–mid-Feb.)	Tar oil	Aphids
Burst Stage (mid-March)	Captan or thiram	Scab
Green Bud (late March)	Captan or thiram DDT	Scab Caterpillar, capsid
White Bud (mid-April)	Captan or thiram	Scab
Full Bloom (late April)	Captan or thiram	Scab
Petal Fall (early May)	Captan or thiram DDT or lead arsenate BHC or nicotine	Scab Codling moth Pear sucker
Early Fruitlet (late May)	Captan or thiram	Scab
Fruitlet (early June)	Captan or thiram	Scab

NOTES

1. *Scab*—Scab sprays should be applied at intervals not exceeding 14

days. For heavy infections of wood scab a copper or mercury fungicide should be used for the first two applications.

2. *Compatibility*—Lead arsenate should not be mixed with thiram.

PLUMS

Prevalent pests and diseases—Aphids, red spider mite, sawfly, caterpillars, bacterial canker, blossom wilt, silver leaf. The last-named cannot be controlled by spraying—see Note below.

TABLE 26: SPRAYING PROGRAMME

Time of spraying	Material	Pests and diseases controlled
Dormant Stage (February)	DNC/petroleum	Aphids, red spider mite, blossom wilt
White Bud (early April)	DDT	Caterpillars
	Bordeaux mixture or copper	Bacterial canker
Cot-split (early May)	White oil	Sawfly
	Derris	
	Methyl-demeton	Red spider mite
Early Fruitlet (mid-May)	Bordeaux mixture or copper	Bacterial canker
Fruitlet (mid-June)	Chlorfenson	Red spider mite
	Copper	Bacterial canker
Leaf Fall (Sept.)	Bordeaux mixture or copper	Bacterial canker

NOTES

1. *Winter washes*—Myrobolan plums should not be sprayed with tar oil or DNC winter washes. Some varieties are best sprayed before Christmas.

2. *Silver leaf*—All dead wood should be cut out and burnt before 15th July each year. Pruning should be carried out in June, July or August.

PEACH AND NECTARINE

Prevalent pests and diseases—Aphids, red spider mite, leaf curl.

TABLE 27: SPRAYING PROGRAMME

Time of spraying	Material	Pests and diseases controlled
December	Tar oil	Aphids
Bud Swelling (late February)	Lime sulphur or Copper	Leaf curl
Pink Bud (early March)	Derris or Chlorfenson or Chlorbenside	Red spider mite
	Lime sulphur or Copper	Leaf curl
Petal Fall (early April)	Derris or Chlorfenson or Chlorbenside	Red spider mite

NOTE
Red spider mite—Additional applications of derris or chlorfenson or chlorbenside may be required.

BLACKCURRANTS

Prevalent pests—Aphids, gall mite (big bud), midge, caterpillar, capsid.

TABLE 28: SPRAYING PROGRAMME

Time of spraying	Material	Pests and diseases controlled
Dormant Stage (Dec.–mid-Feb.)	Tar oil	Aphids
Grape Stage (early April)	Lime sulphur	Gall mite (bigbud)
Blossom Period (late April)	DDT	Caterpillars, capsid, midge
Fruitlet (mid-May)	DDT	Midge

NOTE
Gall mite—Reduced quantities should be used on sulphur-susceptible varieties.

RASPBERRIES

Prevalent pests and diseases—Aphids, beetle, cane midge and cane spot.

TABLE 29: SPRAYING PROGRAMME

Time of spraying	Material	Pests and diseases controlled
Dormant Stage (Dec.–mid-Feb.)	Tar oil	Aphids
Bud Burst (mid-March)	Lime sulphur or thiram	Cane spot
Pre-blossom (early May)	Lime sulphur or thiram	Cane spot
	BHC	Cane midge
Post-blossom (mid-June)	Derris	Beetle
Fruitlet (end-June)	Derris	Beetle

BLACKBERRIES

Prevalent pests—Aphids, capsids, beetle.

TABLE 30: SPRAYING PROGRAMME

Time of spraying	Material	Pests and diseases controlled
Dormant Stage (Dec.–mid-Feb.)	Tar oil	Aphids
Pre-blossom (mid-May)	DDT	Capsid
Post-blossom (early July)	Derris	Beetle
Fruitlet (mid-July)	Derris	Beetle

GOOSEBERRIES

Prevalent pests and diseases—Aphids, red spider mite, caterpillars, capsid, sawfly, mildew.

TABLE 31: SPRAYING PROGRAMME

Time of spraying	Material	Pests and diseases controlled
Dormant Stage (Dec.–Jan.)	Tar oil	Aphids
Pre-blossom (early April)	Lime sulphur	Mildew, red spider mite
Fruit Set (late April)	Lime sulphur	Mildew, red spider mite
	DDT	Caterpillar, capsid, sawfly
Fruitlet (mid-May)	Lime sulphur	Mildew, red spider mite

NOTE

Mildew—Some varieties (Careless, Leveller, etc.) will not tolerate lime sulphur. These may be sprayed with " Karathane " (dinitro (methyl heptyl) phenyl crotonate).

STRAWBERRIES

Prevalent pests and diseases—Aphids, red spider mite, red core, mildew, blossom weevil, grey mould.

Fruiting beds—Schradan in late April and again after picking to control aphids and red spider mite. Lime sulphur or wettable sulphur or " Karathane " applied at 10–15-day intervals during spring and summer to control mildew.

Captan or thiram applied four times at 10-day intervals from early blossom to control grey mould (Botrytis).

DDT or BHC applied late April to control blossom weevil.

Runner beds—Schradan or methyl-demeton in late May and again in late June to control aphids.

Runners—Dip (immerse) runners in nicotine solution before planting to destroy aphids.

Approximate Quantity of Spray Solution required per Acre (fully developed trees)

Cherries—600 gal. tar oil or DNC; 500 gal. other sprays.

Apples—large standard, 600 gal. tar oil or DNC; 400 gal. other sprays. Medium trees—400 gal. tar oil or DNC; 300 gal. other sprays. Small trees—200 gal. tar oil or DNC; 150 gal. other sprays.

Plums—400 gal. tar oil or DNC; 300 gal. other sprays.

Pears—350 gal. tar oil or DNC; 300 gal. other sprays.

Currants—200 gal. tar oil; 150–200 gal. (up to 400 gal. DDT for midge) other sprays.

Gooseberries—150 gal. tar oil; 100–150 gal. other sprays.

Raspberries—150 gal. tar oil; 150–200 gal. (up to 400 gal. derris for beetle) other sprays.

Strawberries—200 gal. schradan; 150–200 gal. other sprays.

VEGETABLES

PLANTING AND SOWING TABLES

Number of plants required to plant a statute acre at various distances

Distance in inches	No. of plants
Brassicas (Brussels sprouts, cauliflowers, cabbage)	
36 × 36	4,840
24 × 36	7,260
24 × 24	10,890
24 × 18	14,520
30 × 18	11,616
24 × 15	17,424
24 × 12	21,780
Celery	
54 × 5	30,000
Onions and leeks	
12 × 6	87,120
12 × 7	69,696
15 × 9	58,080
15 × 6	69,696
18 × 6	60,080

Number of plants required to plant a statute acre at various distances

Distance in inches	No. of plants
Asparagus	
48 × 18	7,260
60 × 18	5,804
36 × 18	9,680
Lettuce	
12 × 12	43,560
12 × 9	58,080
15 × 12	34,848
15 × 9	46,464
18 × 12	29,040
Tomato	
36 × 18	9,680
36 × 24	7,260

QUANTITY OF SEED REQUIRED TO SOW A STATUTE ACRE (APPROX.)

Beans, Broad $1\frac{1}{2}$ cwt.; Dwarf or French, $\frac{3}{4}$ cwt.; Runner (on flat), 1 cwt. Beet, 7 lb. Cabbage (drilled for greens), 5–6 lb.; (for singling), 4 lb. Carrot (for bunching), 6 lb.; (maincrop), 4 lb. Chicory, 8 lb. Cucumber, 2 lb. Lettuce (drilled), 3 lb. Onion (drilled for bulbing), 6 lb.; (drilled for bunching), 30 lb. Parsley, 4 lb. Parsnip, 6 lb. Peas, $1\frac{1}{2}$ cwt. Radish, 56 lb. Spinach (round), 16 lb.; (prickly), 20 lb. Swede, 3 lb. Sweet Corn, 8 lb. Turnip, 2 lb. Vegetable Marrow (bush), 4 lb.; (trailing), 2 lb.

NOTE—Under the Corn Sales Act (Jan. 1, 1923) seeds are bought and sold by weight and not by measure.

QUANTITY OF SEED REQUIRED PER 50 FT. LENGTH OF DRILL

Beet, 1 oz.; carrot, radish, spinach, $\frac{1}{2}$ oz.; lettuce, onion, parsley, parsnip, turnip, swede, $\frac{1}{4}$ oz.; beans, broad, 1 pint; beans, French and runner, $\frac{3}{4}$ pint; peas (early), 1 pint; peas (late), $\frac{3}{4}$ pint.

QUANTITY OF SEED REQUIRED FOR BROADCAST SEED-BEDS

Brassica crops, 1 oz. to 6 sq. yards; celery, 1 oz. to 9 sq. yards.

NOTE—One ounce of cauliflower, broccoli, cabbage or kale seed should produce not less than 3,000 plants, and one

ounce of celery seed not less than 19,000 plants. One ounce of tomato seed should produce 3,000 plants.

QUANTITY OF SEED REQUIRED TO PROVIDE PLANTS FOR TRANSPLANTING

For each acre to be planted—Asparagus, 2 lb.; cabbage, 1 lb.; cauliflower, ¾ lb.; broccoli, ¾ lb.; brussels sprouts, ¾ lb.; celery, 2 oz.; leek, 2 lb.; lettuce, 2 lb.; onion, 3 lb.; savoy, ¾ lb.; tomato, ¼ lb.

SEED TESTING

Seeds Regulations made under the Seeds Act, 1920, apply to certain garden seeds. The Act requires that the garden seeds mentioned in the Regulations shall have been tested for purity and germination *before they are sold or exposed for sale* for seed purposes, and that particulars as to the percentage of purity, if below 97 per cent. (carrot 90 per cent.) and the percentage of germination (or if not less than the authorised minimum, a statement to the effect embodying the authorised minimum) shall be furnished to buyers of seed. Scheduled minimum germinations for vegetable seeds are as follows:—

	per cent.		per cent.
Garden peas	70	Brussels sprouts ...	70
Dwarf and broad beans	75	Broccoli	60
Runner beans	60	Cauliflower... ...	60
Garden turnip and swede	75	Carrot	50
Cabbage	70	Parsnip	45
Kale	70	Beet (of clusters) ...	50
Kohl Rabi	70	Onion	60

Seed Germination

The longevity of seeds varies according to the kind and the method of storage. The table below gives the normal length of life for seeds when properly stored in a cool, dry, airy place:—

Asparagus ...	3 years	Cauliflower ...	5 years
Beans	3 years	Celery	6 years
Beet	3 years	Cucumber ...	5 years
Cabbage	5 years	Lettuce	5 years
Carrot	3 years	Onion	1 year

Parsley	3 years	Sweet Corn ...	1 year
Parsnip	1 year	Tomato	4 years
Peas	3 years	Turnip	5 years
Radish	5 years	Vegetable Marrow	5 years
Spinach	5 years		

SEED DRESSINGS TO CONTROL DISEASES

Disease	Dressing
Black leg of beet... ...	Organo mercurial dust
White rot of onion ...	Calomel (preferably pelletted on to the seed)
Damping off and foot rots of peas and other vegetables	Thiram (TMTD) dusts

HOT WATER TREATMENT OF SEEDS, ETC.

Disease	Temperature and time of immersion
Canker of brassicas ...	122° F. for 25 min.
Alternaria on cauliflower...	122° F. for 18 min.
Black rot of carrot ...	122° F. for 25 min.
Leaf spot of celery ...	122° F. for 25 min.
Mint rust...	Dip runners at 105–115° F. for 10 min.

TABLE 32—GENERAL CONTROL MEASURES FOR VEGETABLE PESTS

Pest	Principal Crops	*Insecticide	Application
Cabbage Root Fly maggot	Cabbage Cauliflower	lindane or gamma BHC aldrin dieldrin	Transplants: To soil around plant within four days of setting out, [illegible] pt. per 8 plants
			Seedbeds: Water on 1 pt. per 5 yd. row; treat as usual after transplanting
			Potted plants: 1 gal. per 115 3-in. pots before planting out

Pest	Principal Crops	*Insecticide	Application
Flea Beetles	Cruciferae Brassicae	lindane	dress seed
		DDT(dust)	to soil surface before seeds germinate and/or to seedlings
Carrot Fly maggot	Carrot Parsnip	lindane dieldrin	dress seed
		dieldrin	spray May and August
	Parsley	lindane	dress seed
	Celery	dieldrin	dip before and spray after transplanting
Pea Moth maggot	Peas (flowering June–mid-July)	DDT (emulsion)	100–150 gal./acre 7–10 days after flowering begins
Onion Fly maggot	Onions Leeks	dieldrin	dress seed
Leaf-eating caterpillars	Brassicae	DDT (dust or emulsion) Derris (dust)	at first sign of damage
Aphids	Brassicae	†schradan †metasystox	for prolonged control
		†tepp nicotine malathion	when harvesting soon
	Beans	†tepp nicotine malathion	before colonies large
	Peas	DDT (emulsion)	as soon as colonies common in growing points

* Follow instructions on labels carefully to ensure good control and to avoid affecting the crop.

† Special precautions to be taken; specified in Agriculture (Poisonous Substances) Regulations, 1956.

A comprehensive list of products and recommended uses is given in "Crop Protection Products Approval Scheme—Approved list: 1957," issued by the Ministry of Agriculture, Fisheries and Food.

Principal Containers used for Marketing Horticultural Produce
RETURNABLES

Description	Measurements in inches	Produce for which used
Bushel box (wood) ..	20 × 13½ × 10	Apples, pears, all vegetables
Half-bushel box (wood)	16 × 11 × 7	Apples, pears, cherries, plums, gooseberries
Quarter-bushel box (wood) ..	13 × 9½ × 6 or 6½	Cherries, currenta, gooseberries, plums
Broccoli crate (wood) ..	22½ × 14 × 14	Broccoli, cauliflower, cabbage, carrots, leeks, turnips
Lettuce crate (wood) ..	20 × 13 × 14	Lettuce, beans, spring onions, radishes
Pot (wicker)	20 × 13 × 14	All vegetables
Half-pot (wicker) ..	15 × 11¾ × 10	All vegetables
Sieve (wicker)	Diameter 17, depth (side) 10½	Apples, pears, some vegetables
Half-sieve (wicker) ..	Diameter 14½, depth (side) 9	Apples, pears, cherries, gooseberries, some vegetables
Flat (wicker)	12 × 15 × 8	Asparagus, runner beans, cucumber
Strike (wicker)	Diameter 11¾, depth (side) 6¾	Currants, cherries, gooseberries, tomatoes
Cross-handle baskets ..	Various sizes	Tomatoes, grapes
Bag	39 × 27	Roots, onions, cabbage, etc.
Half-bag	34 × 18	Roots, onions, cabbage, etc.

NON-RETURNABLES

Description	Measurements in inches	Produce for which used
British Standard—		
Apple box	$18 \times 11\frac{1}{2} \times 10\frac{1}{2}$	Apples and pears
Half apple box ..	$14\frac{1}{2} \times 9 \times 9$	Apples, pears, plums
Quarter apple box ..	$12\frac{1}{2} \times 7 \times 7$	Apples, pears, plums
Tray (single layer) ..	$18 \times 11\frac{1}{2} \times 3\frac{1}{2}$	Apples, pears
Tomato box	$14 \times 9 \times 5\frac{1}{2}$	Tomatoes (12 lb.)
Half-tomato box.. ..	$11 \times 7 \times 4\frac{3}{4}$	Tomatoes (6 lb.)
Cucumber tray (single-layer)	$22\frac{1}{2} \times 17 \times 3$	Cucumbers
Lettuce crate (large) ..	$22\frac{1}{2} \times 16\frac{1}{2} \times 9$	Lettuce, bunched carrots
Lettuce crate (small) ..	$20 \times 13 \times 8$	Spring onions, endive, etc.
Broccoli crate	$22\frac{1}{2} \times 14 \times 14$	Broccoli, cauliflower, cabbage
Asparagus crate (12 bundles)	$21 \times 12 \times 6$	Asparagus
Asparagus crate (6 bundles)	$21 \times 12 \times 3\frac{1}{2}$	Asparagus
Chip basket	Several sizes to hold 2, 4, 6 and 12 lb.	Soft fruit, plums, cherries, tomatoes, mushrooms
Punnets (square, round and rectangular)	Sizes to hold $\frac{1}{4}$, $\frac{1}{2}$ and 1 lb.	Soft fruit, cherries, mustard and cress
Net bag (24 lb.)		Brussels sprouts

THE SALE OF STRAWBERRY PLANTS AND BLACKCURRANT BUSHES ORDER, 1946

This Order requires that no person shall sell, offer or expose for sale or cause to be sold, offered or exposed for sale, or having sold, shall deliver or cause to be delivered any strawberry plants or blackcurrent bushes which are not the subject of a certificate issued by the Ministry of Agriculture for England and Wales or by the Board of Agriculture for the Isle of Man, or by the Department of Agriculture for Scotland or by the Ministry of Agriculture for Northern Ireland or by the Department of Agriculture for Eire.

Notwithstanding the above requirements—

(*a*) The sale of maiden bushes of blackcurrants which are grown from cuttings taken from blackcurrant bushes *which were the subject of a certificate issued in the preceding year* is allowed.

(*b*) Any strawberry plants or blackcurrant bushes which

are the subject of a licence issued by the Minister, may be sold, offered or exposed for sale or planted.

Penalty for contravening the Order or for wilfully or negligently making any statement for the purpose of the Order—sum not exceeding £10; for a second or subsequent offence—not exceeding £50.

THE SALE OF DISEASED PLANTS ORDERS, 1927, 1936–1941, 1943

(*The principal Order is that of* 1927)

Under these Orders it is an offence to sell, offer or expose for sale, or cause to be sold, offered or exposed for sale for planting, or having sold, to deliver or cause to be delivered for planting, any plant substantially affected by any insect or pest mentioned in the *First Schedule* or any plant which bears evidence of having been affected by any insect or pest mentioned in the *Second Schedule.*

First Schedule

(*a*) Fruit and Other Tree Pests

Fruit Tree Cankers (caused by any parasitic fungi or bacteria).

American Gooseberry Mildew (*Sphaerotheca mors-uvae*).

Silver Leaf ((*Stereum purpureum*).

Blackcurrant Mite (*Eriophyes ribis*).

Woolly Aphis (*Eriosoma lanigerum*).

All Scale Insects (*Coccidae*).

Brown Tail Moth (*Nygmia phoeorrhoea*).

Rhododendron Bug (*Leptobyrsa* (*Stephanitis*) *rhododendri*).

(*b*) Vegetable and Root Pests

Powdery or Corky Scab of Potatoes (*Spongospora subterranea*).

Onion and Leek Smut (*Urocystis cepulae*).

Club Root or Finger and Toe Disease (*Plasmodiophora brassicae*).

Second Schedule

Fruit Tree Pest

Apple Capsid (*Plesiocoris rugicollis*).

Additions to Schedules—The Order of 1936 extended the principal (1927) Order to include *inter alia* that the expression

" any plant substantially attacked by any insect or pest mentioned in the First Schedule to this Order " in the principal Order shall be deemed for all the purposes of that Order to include any tomato or cucumber plant which is substantially affected by the insect or pest known as " Greenhouse White Fly " (*Trialeurodes vaporarium*), and any potatoes or Narcissus plants or bulbs which are visibly rendered unfit for planting by reason of their being or having been affected by any insect or pest.

Penalty for contravening the Order or failing to take such steps as are required under the Order or obstructing an Inspector—a sum not exceeding £10; for a second or subsequent offence—a sum not exceeding £50.

GLASSHOUSE CROPS

STANDARD SEED RAISING AND POTTING COMPOSTS

John Innes Seed Compost

Loam (steam sterilised and through $\frac{3}{8}$-in. sieve), two parts (by bulk). Peat (up to $\frac{3}{8}$-in.), one part (by bulk). Sand (coarse up to $\frac{1}{8}$-in.), one part (by bulk).

Plus 2 lb. 18 per cent. superphosphate and 1 lb. ground chalk or limestone per cubic yard, or $1\frac{1}{2}$ oz. superphosphate and $\frac{3}{4}$-oz. ground chalk or limestone per bushel.

John Innes Potting Compost (Standard)

Loam (steam sterilised and through $\frac{3}{8}$-in. sieve), seven parts (by bulk). Peat (up to $\frac{3}{8}$-in.), three parts (by bulk). Sand (coarse up to $\frac{1}{8}$-in.), two parts (by bulk).

Plus 5 lb. J.I. Base (see below), and 1 lb. ground limestone or chalk per cubic yard or 4 oz. J.I. Base and $\frac{3}{4}$-oz. limestone or chalk per bushel.

John Innes Base

(Analysis (approx.) N5·1, P_2O_5 (soluble) 7·2, K_2O 9·7 per cent.) Hoof and horn, $\frac{1}{8}$-in. grist (13 per cent. N.), two parts by weight. Superphosphate (18 per cent. P_2O_5), two parts by weight. Sulphate of potash (48 per cent. K_2O), one part by weight.

NOTE—The J.I. Potting Composts are used with three concentrations of J.I. Base and chalk,, viz. J.I.P.1, the standard potting compost, containing one dose of J.I. Base and chalk; J.I.P.2, containing two doses of the standard

amount of J.I. Base and chalk; J.I.P.3, containing three doses of each. Growth in J.I.P.2 and J.I.P.3 is not necessarily improved or increased initially as compared with J.I.P.1, but the effect is prolonged. The made-up composts and the base are available through the horticultural trade channels.

STEAM STERILISATION OF SOIL FOR PROPAGATION

Pressure Steam (boiler pressure min. 40 lb. per sq. in.)—With suitable apparatus the soil is treated in bins, the soil depth not exceeding 12 in. *Steam* is kept on until all soil is at temperature of 212° F. (five to ten mins.). Steam is then turned off and the soil is left undisturbed for further 10 mins. before use.

CHEMICAL SOIL STERILISERS

Formaldehyde (40 per cent. w/v. Formalin) (used as 2 per cent. water solution): Glasshouse soils, controls soil-borne fungus diseases. Propagating soils—controls soil-borne fungi. Glasshouse and mushroom houses—general disinfectant.

Chloronitrobenzene, proprietary product (used as dusts): Controls Botrytis and other soil-borne diseases.

Cresylic Acid (97–99 per cent. purity) (used as diluted solution): Glasshouse soils—controls root-knot eelworm, soil insect and animal pests.

MARKET GARDENING

A CALENDAR OF OPERATIONS

NOTE—Planting and sowing times vary according to climatic conditions of the district.

JANUARY—*Open land*—Plough, lime and manure land cleared of crops. Cover rhubarb with long litter to advance growth. Lift rhubarb crowns as required for forcing. *Glass-houses*—Sow tomato and cucumber for early main cropping. Plant out lettuce. Sow radish, mustard and cress. Force mint. Sow lettuce. *Frames*—Plant lettuce and sow radish in warm frames. Force asparagus on hot-beds. Give ventilation to plant frames on mild days. *Cloches*—Plant lettuce and sow carrot where soil is warmed. *Forcing Shed*—Force rhubarb, chicory, seakale.

FEBRUARY—*Open land*—Finish ploughing, liming and manuring cleared land. Cultivate and prepare asparagus beds and ridges, apply fertiliser. Sow long-pod broad bean, first early (round seeded) pea, radish (on early land), and parsnip for cropping. Plant shallots. Shake up litter over rhubarb to give aeration. Plant early potatoes in warm areas. Cover seakale for open land forcing. *Glasshouses*—Sow tomato and cucumber for late main-cropping. Plant second crop lettuce. Force mint and salad chicory. Sow onion for plants. Plant cucumbers in prepared borders. *Frames*—Sow early celery, lettuce, onion, cauliflower, cabbage, early brussels sprout on warm bed for plants. Sow turnip, carrot and radish in warm frames. Plant lettuce in cold frames. Force asparagus on hot-bed. Ventilate plant frames on mild days. *Cloches*—Plant lettuce, sow pea, turnip, carrot, radish in warm areas. Sow cauliflower for plants. *Forcing Shed*—Force rhubarb, chicory, seakale.

MARCH—*Open land*—Sow onion, early carrot, second-early pea, long-pod and Windsor broad bean, parsnip and radish for cropping. Sow leek, cabbage (summer), brussels sprout, cauliflower for plants. Plant Jerusalem artichokes, early ptoatoes, asparagus, seakale, horse-radish, mint, rhubarb, lettuce (from frames), onions (autumn sown) and garlic. Plant cauliflowers from frames in warm areas. *Glasshouses*—Plant tomatoes and cucumbers. Force mint, chicory. Sow bean (for cropping under glass), tomato (for open land crop), melon (for crops under glass). *Frames*—Sow carrot and turnip in cold frames. Sow celery for plants. *Cloches*—Sow turnip, carrot, radish, globe beet, sweet corn. Plant lettuce and cauliflowers. Cover strawberries. Sow lettuce for plants. *Forcing Shed*—Continue forcing of chicory and seakale.

APRIL—*Open land*—Sow early beet, carrot, turnip, salsify, sweet corn, radish, lettuce, spinach, parsley, maincrop pea and French bean (in warm areas) for cropping. Sow cabbage, kale, broccoli, savoy for plants. Plant onions (plants from glasshouses and frames), cauliflowers (from frames), lettuce (from frames), second-early and maincrop potatoes, and mint. *Glasshouses*—Sow marrow and melon for plants. Transfer tomato plants to frames to harden for open land cropping. *Frames*—Plant melon in warm frames.

Harden tomato plants by ventilating freely. *Cloches*—Plant tomatoes, sow French and runner bean, sweet corn, cucumber. De-cloche advanced crops as weather permits.

May—*Open land*—Sow carrot, turnip, runner bean, French bean, endive, cos and cabbage lettuce, late beet, spinach, spinach beet, ridge cucumber, gherkin, marrow, late pea, radish (on cool moist sites) for cropping. Plant cabbage (summer), brussels sprouts, cauliflowers, early broccoli, early leeks, tomatoes, celery, New Zealand spinach. Sow broccoli, savoy and cabbage for plants. Sow chicory for roots to force. *Frames*—Plant melons and cucumbers on warm beds in cold frames. *Cloches*—Plant melons end of month. Sow marrow. Plant tomatoes.

June—*Open land*—Finish cutting asparagus by middle of month. Finish pulling rhubarb and apply fertiliser to beds. Sow carrot, turnip, endive, lettuce, late pea for cropping. Plant brussels sprouts, broccoli, winter cabbage, savoys, celery and leeks. De-cloche ridge cucumbers and tomatoes. *Cloches*—Plant melons. De-cloche runner beans and sweet corn when weather warm. *Glasshouses*—Second crop cucumber may be sown. Clean and re-soil houses before planting second crop.

July—*Open land*—Sow French bean and carrot for late cropping. Harvest shallots. Sow spinach beet for cropping. Sow spring cabbage (late half of month) for plants. Sow turnip for winter storage. Sow endive for autumn cropping. *Cloches*—De-cloche tomatoes and cucumbers.

August—*Open land*—Sow spring (salad) onion and winter spinach for cropping. Sow onion, cabbage and lettuce (cos and cabbage) for autumn plants. Harvest autumn-sown onions. Plant strawberries. Mound up celery. Plant endive. *Glasshouses*—Plant tomatoes for late cropping. Sow French bean for ditto. *Cloches*—Sow French bean for late cropping.

September—*Open land*—Harvest spring-sown onions. Sow turnip for "turnip-tops." Plant spring-cabbage. Sow lettuce and cauliflower early in month for plants. Sow lettuce (cabbage) for over-wintering crop. Mould celery. *Glasshouses*—Clear tomato plants as crop finishes. Wash down and disinfect houses. Arrange for soil steaming (if necessary).

Frames—Prepare frame sites for sowing. Repair damaged lights. Sow cauliflower for plants. *Cloches*—Prepare cloche sites for cropping.

OCTOBER—*Open land*—Lift maincrop potatoes, carrots, beet, turnips for storage. Lift chicory and seakale for forcing. Clear asparagus beds and ridges of dead-growth and weeds; re-soil and manure. Plant cos and cabbage lettuce for over-wintering crops. Blanch endive. Mould celery. Trim, fork and manure rhubarb beds. *Glasshouses*—Steam soil of tomato houses; trench and manure beds, apply basic fertiliser and flood beds. Sow lettuce for plants. Lay in fuel stocks. *Frames*—Sow cabbage lettuce. Sow further batch of cauliflower. Prick out plants of earlier sowing. Prepare sites and hot-beds for warm frame cropping. Blanch endive in cold frames. *Cloches*—Cover lettuce and endive for autumn and early winter. Sow lettuce and cauliflower. Prick out cauliflowers and lettuce. *Forcing Shed*—Prepare for forcing season. Clean and disinfect shed and beds. Prepare heating apparatus and lay in fuel stocks.

NOVEMBER—*Open land*—Plough and manure vacant land. Apply lime where necessary. Sow long-pod broad bean and round-seeded pea for early crops. Lift mint roots for forcing under glass. Lift rhubarb for forcing. Lay in stock of fertilisers. *Glasshouses*—Force mint. Plant lettuce for winter crops. Lay in fuel stocks. *Frames*—Prick out lettuce—Continue care of cold and warm frames. Blanch endive in cold frames. *Cloches*—Sow pea for early crop. *Forcing Shed*—Force rhubarb, seakale, chicory.

DECEMBER—*Open land*—Plough and manure vacant land. Apply lime where necessary. Tray seed potatoes for sprouting. Lift rhubarb and asparagus for forcing. *Glasshouses*—Prepare beds for, and sow mustard and cress. Force mint. Sow tomato and cucumber for early cropping. *Frames*—Give ventilation to plant frames on mild days. *Cloches*—Give ventilation on mild days. *Forcing Shed*—Force rhubarb, seakale, chicory.

DISEASES OF CROPS

CHEMICAL PREVENTIVE MEASURES

SEED DRESSING

SEED-BORNE diseases—Organo-mercurial seed dressings which have an eradicant action are used against certain seed-borne smuts and leaf stripe in cereals and against black-leg in beet. The dressings also give some protection against soil-borne foot rots.

Soil-borne diseases—On peas and vegetables seed-borne diseases are not important but soil-borne fungi such as *Pythium spp.* cause seed decay and pre-emergence damping-off. For soil-borne diseases protective dressings containing thiram or captan give better results and are safer on the plant than organo-mercurials.

SPRAYING

Spraying against diseases of cereals is generally not practicable in this country. On row crops such as potatoes and on fruit crops the development of low volume machines has made spraying very economic.

COMMON FUNGICIDES

In the past, apart from the organo-mercurial seed dressings, most fungicides have been simple forms of copper or sulphur. To-day the tendency is to replace these with organic fungicides which are safer on the plant.

The **Copper** fungicides now used are mainly proprietary forms of copper oxide or copper oxychloride. These are safer on the plant than the older Bordeaux mixture. Suitable formulations can be applied low volume whereas Bordeaux must be applied high volume. For farmers who still wish to make their own Bordeaux mixture the formula is given below.

Bordeaux mixture:—

Copper sulphate (powdered or granular)	10 lb.
Lime (best hydrated)	12½ lb.
Water	100 galls.

Burgundy mixture contains 12½ lb. of washing soda instead of hydrated lime. The copper sulphate should be at least 98 per cent. pure and the hydrated lime purchased fresh.

In preparing the mixture the copper sulphate should be dissolved in 5 gallons of water and the lime or washing soda in 95 gallons. The two solutions should then be mixed.

Lime Sulphur is still a commonly used fruit spray but dispersible or colloidal sulphurs are safer on varieties susceptible to sulphur shock.

Organic fungicides at present in common use include:—

Thiram—An organic form of sulphur. Safe on plants liable to sulphur shock. Widely used in seed dressings for peas and vegetables and on fruit crops.

Captan—Particularly effective against apple scab. Now being tested in seed dressings for peas and vegetables. Does not control powdery mildews.

Zineb—The best known in this country of the dithiocarbamate group of chemicals. A safe material for potato blight.

Chloronitrobenzenes (*Tecnazene* (*TCNB*) *PCNB*)—Useful general soil fungicides for diseases such as Botrytis and Fusarium. *TCNB* protects clamped potatoes against dry rot. *PCNB* is a safe seed dressing specific for wheat bunt.

CEREALS AND GRASSES

Yellow Rust (*Puccinia glumarum*)—The most damaging cereal rust in Britain. Affects wheat, barley and occasionally rye, but not oats. Also attacks certain grasses. Lemon-yellow pustules in parallel lines on leaves and stems. Scarce after very hard winters or unusually hot summers. Control consists of selecting resistant varieties.

Black Rust (*Puccinia graminis*)—Occurs on wheat, oats, barley, rye and several grasses, but in Britain develops late and is rarely damaging. The fungus alternates between cereals and the common barberry (*Berberis vulgaris*). On cereals it forms reddish brown, later black, lines or spots on the leaf sheaths and stems: and on the barberry produces yellow or orange-coloured cluster cups. The disease is not

very common in this country. Where troublesome destroy barberry and choose the more resistant varieties.

Bunt or Stinking Smut (*Tilletia caries*)—Common on wheat, rare on rye. Difficult to detect until ears emerge. The grain of bunted ears becomes filled with a black mass of greasy spores that smell fishy. The bunted grains burst during threshing and the spores contaminate and discolour the healthy grain, spoiling it for milling and seed purposes.

Control consists of disinfecting the seed with an organo-mercurial seed dressing. Treated grain can be fed to poultry or pigs after washing with water, and bulking up with untreated grain. If stored, must be kept dry and germination must be tested before sowing.

Covered Smut of Barley (*Ustilago hordei*), **Covered Smut of Oats** (*Ustilago kolleri*), **Loose Smut of Oats** (*Ustilago avenae*)—These diseases are similar in appearance to bunt.

Control consists of using an organo-mercurial seed dressing.

Loose Smut of Wheat (*Ustilago tritici*) **and Loose Smut of Barley** (*Ustilago nuda*)—The black smutty ears are conspicuous soon after emergence from the leaf sheaths.

The fungus is too deeply seated for seed dressing to be effective. Use seed only from clean crops. Hot water seed treatment has been used but is difficult to apply.

Leaf Stripe (*Helminthosporium gramineum*) of barley and **Leaf spot** (*H. avenae*) of oats occur mainly in the west and north. May kill young seedlings before emergence or produce brown stripes or spots on leaves and sheaths. Use organo-mercurial seed dressing.

Net Blotch (*H. teres*)—Not quite so common as the leaf-stripe. Distinguished by a criss-cross network of brown marks on the leaf. Use organo-mercurial seed dressing.

Take-all (*Ophiobolus graminis*) affects wheat, barley and certain grasses (mainly couch, Yorkshire fog and bent), especially on light alkaline soils. Rye is resistant and oats almost immune to this fungus, but a special strain of it (*var. avenae*) occurs on oats, wheat and barley in Wales, north-west

England and Scotland. Both fungi attack the roots leading to black discoloration at base of stem and empty bleached ears, " Whiteheads."

To control the disease ensure a break from cereals every two or three years in rotation. Keep down perennial grass weeds. Maintain high fertility particularly with nitrogen and phosphate. Use acid fertilisers such as superphosphate and *not* alkaline ones.

Eyespot (*Cercosporella herpotrichoides*)—In spring this causes oval brown-bordered spots, shaped like an eye, on the leaf sheath of wheat, barley and occasionally oats. Later these weakened plants " Lodge."

To control, reduce frequency of wheat and barley in the rotation and choose short strawed varieties and top dress generously with nitrogen. Some varieties are more resistant than others (e.g., Capelle). Late autumn sowing will reduce attack.

Mildew (*Erysiphe graminis*)—On all cereals and most grasses. When severe leads to badly filled ears and shrivelled grain. Worst when mild winter followed by dry spring. Avoid too thick sowing and unbalanced manuring. Sheep off in spring to hasten recovery from early severe attack.

Ergot (*Claviceps purpurea*) is commonest in rye and ryegrasses. Wheat and barley sometimes attacked. Blackish " horns " up to $\frac{3}{4}$ in. long displace the young grains. Treatment consists of deep ploughing and crop rotation. Use clean seed or seed freed from ergot by floating in a saturated salt solution.

Blind Seed Disease (*Phialea temulenta*) affects ryegrasses and occasional fescues. Can be recognised only in the seed. Infected seeds are killed and seed samples containing them give low germination figures. Avoid infected seed stocks.

Choke (*Epichloe typhina*)—White or yellow cylinders of fungus felt up to 2 in. long round leaves and stems of cocksfoot, timothy and other grasses. Infected plants never recover. Interferes with seed production and is possibly seed transmitted. No satisfactory treatment has yet been discovered.

Brown Foot Rot and Ear Blight (*Fusarium spp.*)—Thin stand, yellowish leaves and poor root systems. Later affects ears causing pink or red mould. Not very important in this

country and usually only in poorly drained acid soils. Organo-mercurial seed dressings have some effect.

Grey Leaf (Manganese deficiency) is most conspicuous in oats on alkaline soils. Grey or buff blotches and streaks on leaves, especially at margins. In spring apply 50 lb. per acre of manganese sulphate or, better still, spray with a 1 per cent. solution.

POTATOES

Blight (*Phytophthora infestans*)—Produces dark blotches on leaves and in wet seasons may completely kill haulms. Also responsible for reddish-brown markings below skin of tubers, often leading to severe rotting in clamps. Develops under warm damp conditions. Protect foliage by spraying with approved copper or organo fungicide or with Bordeaux mixture. Protect tubers by cutting and removing haulm or by killing it with sodium arsenite, sulphuric acid, sodium chlorate or tar acids a week or so before the crop is harvested.

Dry Rot (*Fusarium caeruleum*) develops in stored tubers during the winter months under warm damp conditions, especially in early varieties. Large sunken, wrinkled areas usually beset with white or pinkish spore pustules. Handle tubers carefully to avoid wounding. Dust with TCNB within 48 hours of lifting (which also acts as a sprout-repressant). Organo-mercurial dips may be used for tubers saved for seed.

Wart Disease (*Synchytrium endobioticum*) is scheduled as a notifiable disease. Produces greenish-yellow warty cauliflower-like growths on the tubers and on the stalks near soil level. Fungus remains alive in contaminated soil for many years. Grow immune varieties.

Common Scab (*Actinomyces scabies*)—Brown scurfy spots or patches on the tubers. Troublesome in sandy or gravelly, alkaline soils and on newly ploughed grassland. Plough in green crop such as mustard, rye or vetches. Apply acid forming fertilisers such as sulphate of ammonia. Organo-mercurial dips may be used before planting.

Powdery Scab (*Spongospora subterranea*)—Not always easy to distinguish from Common scab. Rounded scabs on tubers or extensive cankered areas due to secondary growth

of the tuber. Use clean seed. Drain wet soils. Rotate crops.

Black Leg (*Bacterium phytophthorum*)—From June onwards causes blackening and rotting of the stem base, leaves turn pale green, then brown and stems die off. Tubers become infected with soft brown rot from heel end.

Leaf Roll and Rugose Mosaic (Viruses)—Rolling of the lower or uppermost leaves, or dwarfed plants with yellow-green mosaic foliage. Tubers few and small, yields low. Always plant certified seed. Rogue out affected plants early. Experiments are now being conducted with systemic insecticides to kill the aphids which transmit the virus. DDT emulsion has been used with success as a preventive combined with a routine copper spray.

ROOT CROPS

Club Root (*Plasmodiophora brassicae*)—Also called Finger-and-Toe and Anbury. Causes swellings and contortions of roots of swede, turnip, rape, cabbage and other brassica crops in acid soils. Incorporate freshly slaked burnt lime, hydrated lime or ground quick lime with the soil. This may take 18–24 months to work, otherwise, long rotation (seven years or more) is necessary. Use resistant varieties of swedes and turnips. Raise plants in clean seed bed and where practicable dip cabbage seedlings, etc., in calomel paste (3 lb. calomel in 1 pint water per 300 plants) before transplanting. Alternatively apply corrosive sublimate at 1 in 2,000 at ½ pint to each dibble hole.

Scab (*Actinomyces scabies*)—Sometimes severe on turnip, sugar beet and mangold in alkaline soil. This is checked by green manuring and acid forming fertilisers.

Black Leg (*Phoma betae* and *Pythium spp.*)—Stems of very young sugar beet and mangold seedlings become black and threadlike. Seedlings wilt and die. The Phoma is seed borne. Use an organo-mercurial seed dressing.

Violet Root Rot (*Helicobasidium purpureum*)—Attacks many plants, including sugar beet, mangold, potato, carrot and clover. Affected parts become covered with purple felt of fungus mycelium. Careful rotation needed with improved soil drainage and fertility.

Downy Mildew (*Peronospora schachtii*) of sugar beet and mangold causes heart leaves to become pale green, thickened and covered with lilac-grey downy fungus. Fungus spreads from root to seed crops and vice-versa. Keep root and seed crops well separated.

Yellows (**Virus**) of sugar beet and mangolds. Outer and middle leaves become orange-yellow, thickened and brittle. For every week a plant shows symptoms up to mid-October it loses 5 per cent. of its potential yield of sugar. Keep root and seed crops separate. Sow early and clear mangold clamps by end of March. Spraying with systemic insecticides to kill the aphids which transmit the virus is now giving good results.

Heart Rot (Boron deficiency) of sugar beet and mangolds. Usually in alkaline soils. Heart leaves wilt, become black and die. Brown decay round shoulder of tap root. Apply 20 lb. borax per acre.

CARROTS

Sclerotinia Disease (*Sclerotinia sclerotiorum*)—Causes extensive rotting in storage, usually beginning at crown. Copious growth of white mycelium and black resting bodies. Destroy infected material and ventilate store or clamp. Other susceptible crops such as parsnip, beet and potatoes should not be grown for three years on affected land.

PARSNIP

Canker (non-parasitic)—Transverse cracking at crown of root, especially in broad shouldered sorts with stubby roots, often follows on certain weather conditions. Secondary organisms invade and cause roots to become black and rotten. Apt to carry in lime deficient soil and after unbalanced feeding with nitrogen. Canker may follow injury by carrot fly and canker itself is often confused with carrot fly damage. Control consists of good cultivation and balanced fertilising.

FLAX AND LINSEED

Rust (*Melampsora lini*)—Yellow or orange pustules on leaves, stems and flowers, followed later in year by black

pustules. Grow resistant varieties and avoid using seed from heavily rusted crops. Sow early.

Wilt (*Fusarium lini*)—The main cause of flax " sickness." Plants wilt in patches. Fungus persists in soil for many years. Rotate crops or select resistant varieties and destoy all infected plant debris.

Seedling Blight (*Colletotrichum linicola*), **Stem-break and Browning** (*Polyspora lini*) and certain seed-borne diseases. Treatment is thiram seed dressing.

BEANS AND PEAS

Chocolate Spot (*Botrytis cinerea* and *B. fabae*)—Sienna brown spots on leaves of field and broad beans. Becomes aggressive in warm wet weather after late spring frosts, and shoots then blackened and killed. Rarely bad on spring sown beans. Also occurs on vetches. To control, correct potash and phosphate deficiency and ensure adequate drainage.

Leaf and Pod Spot (*Ascochyta spp.*) of peas—Brown or purple-brown spots on leaves, stems and pods. Seedlings often killed. Carried in seed, hence sow only healthy seed and rotate crops. Burn off infected haulm.

Foot Rot (*Fusarium spp.*) of peas—Patches of plants die. Roots and stem bases brown or black and decayed. Often associated with eelworm on roots. Rotate crops. Use thiram or captan seed dressing.

Pre-emergence Damping-off of peas—Seeds fail to germinate or seedlings rot before emergence. Occurs especially in early sowings if soil cold and wet. Use thiram or captan seed dressing.

Marsh Spot (manganese deficiency) of peas—Seeds appear normal, but when cut across reveal dark brown spot in centre. Spray with manganese sulphate at flowering time. Lime should *not* be applied.

PASTURE AND FORAGE CROPS

Rot (*Sclerotinia trifoliorum*)—One cause of clover " sickness." Especially on broad red clover. Frequent on trefoil, and on first-year sainfoin and lucerne. Plants rot off in irregular

patches over field. Adopt a rotation of 8–12 years. Avoid sowing red clover among wheat after beans.

HOPS

Downy Mildew (*Pseudoperonospora humuli*)—Dwarf curled bines (basal spikes) in spring, followed later by similar lateral and terminal spikes. Fungus also causes angular leaf spotting and cone browning. The root stock when affected gradually rots. Affected parts become covered with dark grey, velvety, fungus growth. Treatment consists of removing and burning all spikes. Strip lower leaves in stages and spray with proprietary copper or Bordeaux mixture.

Wilt (*Verticillium albo-atrum and V. dahliae*)—Occurs in two forms: a mild " fluctuating " form and a severe " progressive " wilt. Yellowing and browning of leaves followed by death of bine, which is usually thickened. " Progressive Wilt " is a notifiable disease. Destroy all wilting bines and grub badly affected hills. Plant sets from certified gardens using resistant varieties, e.g., Keyworth's Early or Keyworth's Midseason.

Nettlehead (**Virus**)—Thin, weak and unfruitful bines which cannot climb properly. Grub affected plants. **Mosaic** (*virus*) plants with mottled foliage should also be rogued out. Plant sets from certified gardens. (See Hop varieties, page 135.)

Hop Mildew (*Sphaerotheca humuli*) forms white spots on leaves: attacks the " burr " (female flowers) preventing cone formations, and late attacks cause the cones to assume a foxy red colour—" Red Mould." Strip lower leaves. Burn affected bines after picking. Spray or dust with sulphur.

Canker (*Fusarium sambucinum*) attacks the base of the bines causing them to become detached from the root-stock. Generally not a serious disease. Cut away dead portions of root-stock in spring.

TOP FRUIT

Scab (*Venturia inaequalis*) of apple—Olive green patches on leaves and sooty scabs on fruit. The main infection comes in spring from ascospores discharged from old fallen leaves. Infection periods can occur at any time from bud burst onwards depending on a suitable combination of temperature

and moisture conditions. Spray with lime sulphur or proprietary organo-mercurial fungicide. On sensitive varieties use dispersible sulphur or organic fungicide such as captan. Regular spraying at 10-day intervals from bud burst onwards is necessary for best results.

Scab (*Venturia pyrina*) of pears—Symptoms are similar to apple scab. Spray with copper, sulphur or an organic fungicide.

Mildew (*Podosphaera leucotricha*) of apple—White mealy powder on young leaf trusses. Cut out infected shoots. Spray with lime sulphur or dispersible sulphur plus wetter.

Blossom Wilt (*Sclerotinia laxa*) of apple, pear, plum, cherry, blossoming and cankering of spurs. Remove all cankers and infected spurs. Tar oil winter washing, may give some reduction in attack.

Brown Rot (*Sclerotinia fructigena*) of apple, pear and plum. Rapid brown rot of fruit beginning at wounds. Buff spore pustules on rotted parts. Fruits become mummified and hang on trees. This is controlled by good orchard hygiene.

Silver Leaf (*Stereum purpureum*)—Common on plum, cherry and peach, occasional on apple. Leaves show silvery or leaden sheen: branches die back and flattish purple fructifications develop on dead bark. Cut out and burn all dead wood by 15th July. Cover fresh wounds with white lead paint.

Bacterial Canker (*Pseudomonas mors-prunorum*) of plum and cherry. Shot-hole of leaves: sudden wilting and death of part or whole of tree in spring. Spray with proprietary copper or Bordeaux mixture in spring and autumn.

Leaf Curl (*Taphrina deformans*) of peach, nectarine and almond. Reddish, thickened, curled or distorted leaves. Bordeaux or Burgundy mixture. Spray when flower buds begin to swell with proprietary copper or Bordeaux or Burgundy mixture. Repeat ten days later.

INSECT PESTS OF CROPS

CERTAIN soil pests will attack and seriously damage many crops, the most important being wireworms, leather jackets, cutworms and slugs.

Wireworm (*Agriotes spp.*)—Crops which are most liable to damage are cereals, sugar beet and other root crops, potatoes, tomatoes, carrots and strawberries. Peas, beans, linseed and mustard are relatively resistant.

Damage is usually most serious after ploughing permanent pasture, but populations can build up appreciably after leys of three or more years duration. Crops are better able to withstand attacks when sown in well prepared and consolidated seed beds.

Seed dressings based on *gamma*-BHC, dieldrin or aldrin, provide adequate protection for cereals and sugar beet, providing the wireworm population is less than about 600,000 per acre. With heavier infestations and where seed dressing is not possible, aldrin or *gamma*-BHC should be applied broadcast, and worked into the soil before drilling or planting the crop. *Gamma*-BHC is used as a low concentrate dust at the rate of $\frac{3}{4}$–1 lb. of insecticide per acre, and aldrin at the rate of 2–3 lb. per acre as a dust, or a spray, or compounded in fertiliser. As an alternative to broadcasting, aldrin or *gamma*-BHC dusts or aldrin/fertiliser may be combine-drilled with suitable crops at about half the above rates. As potatoes are susceptible to tainting from *gamma*-BHC it is preferable to use aldrin if potatoes are to be planted within eighteen months of treatment.

Leatherjackets (*Tipula spp.*)—Leatherjacket damage is most likely to occur after ploughed up grassland. Early ploughing, before egg laying in August, helps to prevent infestations in the succeeding arable crop. Broadcast applications of aldrin or *gamma*-BHC, as recommended for wireworm, also control leatherjackets and cutworms. If treatment is deferred until an attack starts, DDT, *gamma*-BHC, aldrin or dieldrin sprays may be used, or these insecticides may be broadcast with bran as a bait. Paris Green/bran baits are also effective.

Slugs (*Limacidae*)—Slug damage is particularly serious on heavy land in mild and wet seasons during autumn, winter and early spring.

Complete control during autumn and winter is difficult but infestations may be reduced appreciably by means of baits or sprays.

The most effective bait is a mixture of 1 lb. of Paris Green and 1 lb. of powdered metaldehyde with 25 lb. of bran, broadcast at the rate of 25–40 lb. per acre. Metaldehyde may also be used as a spray and this method of application is often more convenient than broadcasting a bait. Sprays of 0·1 per cent. copper sulphate have also been used with success, and autumn or winter spraying with DNC weed-killer, where this is possible, is also effective.

Chafers (*Phyllopertha horticola*)—Infestations of chafer grubs are usually only of local importance and may be controlled by broadcast applications of aldrin or *gamma*-BHC, in the same manner as for wireworm.

CEREAL PESTS

Wheat Bulb Fly (*Leptohylemyia coarctata*)—Late sown winter wheat is most liable to damage. Barley and rye are occasionally attacked but oats are immune. Preferred egg-laying sites are bare fallows and loose dry soil in main crop potatoes, and to a less extent root crops and kale. There is less risk of damage if wheat is grown after other corn crops, mustard, or harvesting peas.

Damage can be minimised by drilling wheat before mid-November, and selecting varieties which tiller and establish quickly. Deep drilling should be avoided.

Appreciable protection may be provided by dressing the seed with dieldrin, aldrin or *gamma*-BHC seed dressings. A greater concentration of insecticide than for wireworm control is needed to protect wheat against bulb fly, and special seed dressings are now available for this purpose. These also give protection against wireworm and seed-borne diseases, and are recommended for routine use in districts where wheat bulb fly is prevalent.

Frit Fly (*Oscinella frit*)—Spring oats are attacked by the larva in the seedling and tillering stages and a second generation attacks oats in panicle, damaging the grain.

Early sowing enables the crop to withstand attack, and damage is unlikely to be serious if the "4-leaf" stage is reached by early May. A well-prepared seedbed and adequate fertiliser also encourage quick germination and development.

Control measures should be directed against the first generation. Dieldrin sprays applied in early May have proved effective, and may be mixed with MCPA weedkiller if the timing is appropriate.

Cereal Root Eelworm (*Heterodera major*)—This pest has increased in intensity of recent years due to more frequent cereal cropping. Oats and to a lesser extent other cereals are attacked. Cysts formed on the roots persist in the soil for many years and multiply year by year in the presence of susceptible crops.

No effective chemical control is available, but the population of eelworms can be kept down to reasonable proportions by suitable rotational cropping.

Stem and Bulb Eelworm (*Ditylenchus dipsaci*)—Seedling oats are attacked, and affected plants become swollen and distorted. Adequate rotation and destruction of susceptible weeds is the only remedy.

POTATOES

Potato Root Eelworm (*Heterodera rostochiensis*)—This "cyst-forming" eelworm is prevalent in many potato growing areas, and where infestation is heavy potatoes cannot be grown successfully. No effective and economic means of chemical control is available, but populations may be kept down to reasonable proportions by practising long rotations, and destroying susceptible weeds and "ground-keepers."

CABBAGE CROPS

Cabbage Aphis (*Brevicoryne brassicae*)—This is a serious pest of brussels sprouts and other cabbage crops. The entire life cycle of the pest is spent on cabbage crops, and the destruction of crop remains together with over-wintering eggs which they carry, is an important preventive measure.

The aphids are difficult to contact and spraying with a systemic insecticide, such as schradan or methyl-demeton, provides the best control. These sprays should be applied

thoroughly so as to reach colonies in the hearts of plants, and they should not be used within one month of harvesting.

Cabbage Root Fly (*Erioischia brassicae*)—Roots of cruciferous plants, particularly cauliflowers, are attacked by the larvae, causing either complete destruction or loss of weight and quality.

Effective control is provided by aldrin, dieldrin or *gamma*-BHC, used as emulsions or wettable powders. These may be applied, suitably diluted, around the base of plants within a few days of transplanting after the middle of April. Alternatively, aldrin or dieldrin wettable powders or emulsions may be used as root dips. Plants should not be soaked in the solution or packed tightly in crates for transportation to the field while they are still wet. They should be planted as soon as possible after dipping.

Flea Beetles (*Phyllotreta spp.*)—Sowings from mid-April to mid-May are most susceptible to attack. Steps should be taken to encourage quick germination and early seedling growth by good seedbed preparation. Once seedlings have reached the rough leaf stage, they are usually able to grow away from the attack.

All seed of brassicas, turnips, vetches and mustard, should be dressed as a routine measure, with a seed dressing based on *gamma*-BHC or dieldrin. This provides useful protection up to the rough leaf stage, and often further control measures are unnecessary. With severe attacks, or when the pest appears after the rough leaf stage, further spraying with DDT or dieldrin emulsion in low volume, may be necessary. Alternatively, DDT or *gamma*-BHC dusts may be used.

Cabbage Caterpillars, Cabbage white (*Pieris brassicae*), **Cabbage Moth** (*Mamestra brassicae*), **Diamond Back Moth** (*Plutella maculipennis*)—Caterpillars of the Cabbage white butterfly, Cabbage moth, and Diamond back moth are well-known pests of brassicas. Steps should be taken to control them before the infestation builds up to serious proportions, by spraying or dusting with DDT.

Turnip Gall Weevil (*Ceuthorhynchus spp.*)—Galls are produced by the larvae on the roots of turnips, cabbages and other cruciferous crops, and are frequently confused with club root damage. The same control measures as for cabbage root fly are appropriate.

FORAGE CROPS

Clover Weevil (*Apion spp.*)—This pest is responsible for serious reductions in yield of clover seed, and routine spraying is advisable because excellent control can be obtained at low cost. DDT or dieldrin emulsion sprays should be applied in low volume to kill the adult weevils on the crop before they lay eggs in the flower buds. One spray is usually sufficient if applied 10–14 days after first cut, and before the flower buds form. DDT dusts may be used if spraying is not possible, but are less effective.

Lucerne Weevil (*Phytonomus spp.*)—Lucerne foliage is damaged, and also seed heads of sainfoin and trefoil. An attack on seedling lucerne can be serious.

If lucerne is cut late, when the larvae are well grown or have pupated, a large proportion are removed with the hay, but a further attack on the second cut frequently results from early cutting.

Spraying in late April before crop growth becomes too dense, is effective, using DDT or dieldrin emulsions in low or medium volume. DDT dusts may also be used successfully.

PEAS AND BEANS

Pea and Bean Weevil (*Sitona spp.*)—Damage consists of injury to the leaves and stems of seedling peas and beans, and other legumes, which is most serious with poor growing conditions and rough seedbeds.

The pest is easily controlled by spraying with DDT or dieldrin emulsion, or dusting with DDT, but early application is important for maximum effect. The weevils come into the crop from the field surrounds, and early spraying or dusting of the outsides of the crop only, before the pest disperses over the crop, is sometimes effective.

Pea Moth (*Cydia nigricana*)—The " maggots " frequently found in pea pods are the larvae of this pest. Late sown crops are most often attacked, and early varieties frequently escape damage.

Precautionary measures include growing peas as far as possible from fields which were cropped with peas in the previous year, and removing and disposing suitably of haulm from fields which have been harvested, as soon as possible.

A DDT emulsion spray should be applied 7–10 days after the first flowers open, using not less than 100 gallons per acre of solution, and fairly high spray pressure. With harvesting varieties, this spray should be repeated 14 days later. This treatment also controls aphis and thrips.

Pea Aphis (*Macrosiphum pisi*)—In bad aphis years serious reductions of yield and poor quality peas are commonly experienced. Early varieties are less subject to attack.

Spraying should be carried out if colonies are found on about one in five plants. DDT sprays are effective if applied thoroughly in a high volume of water. Methyl-demeton may also be used to within four weeks of harvesting. If infestation occurs within this period a non-persistent insecticide such as TEPP may be used provided the crop is not harvested for 48 hours after spraying.

Pea Midge (*Contarinia pisi*)—Pea midge is fairly localised in its attacks, but it can be a serious pest. The small white grubs attack the peas, and also damage the buds, and cause sterile flowers. Timing of sprays to obtain effective control is not easy, and two applications of DDT emulsion in high volume at fortnightly intervals are usually necessary. A close watch for the presence of midges should be kept on the crop from the beginning of July, and the first spray applied as soon as they are observed in any quantity.

Pea Thrips (*Kakothrips robustus*)—This is not usually a pest of major importance but heavy infestations can restrict pod development and reduce yields. Spraying with DDT, as for aphis, provides adequate control.

Pea Eelworm (*Heterodera goettingiana*)—This pest is increasing in importance in pea growing areas, due to close rotational cropping. Severe attacks are evidenced by poor growth and pale foliage, usually in patches throughout the field. With lighter infestations there are often no visible symptoms, but yields may be reduced.

In order to prevent the spread of this serious pest, peas should not be grown more frequently than once in four years, and a longer interval allowed if possible. No chemical control can be recommended.

Bean Aphis (*Aphis fabae*)—The bean aphis or " Black fly " attacks many cultivated plants and weeds, and is the

most serious pest of field beans. Spring sown beans are most seriously affected, but substantial increases in yield may be obtained by one well-timed spray of methyl-demeton or schradan. The spray should be applied at the end of the period of primary migration into the crop, approximately mid-June, and the crop sown as early as possible.

Bean Seed Fly (*Delia spp.*)—French and runner beans are often severely damaged in the seedling stage. Control may be effected by dieldrin seed dressings, or by a broadcast application of aldrin dust, as for wireworm, or by applying aldrin dust to the drills at sowing time.

ROOT CROPS

SUGAR BEET, FODDER BEET AND MANGOLDS

Aphids: Black Aphis (*Aphis fabae*), **Peach Aphis** (*Myzus persicae*)—Black aphis and peach aphis can cause considerable reduction of crop by direct damage, and the latter species is also the principal vector of Virus yellows.

Steps should be taken to control both pests by spraying with methyl-demeton or schradan, using medium to high volume of water. Field crops should be sprayed in June, in the early stages of infestation. Two sprays at three-week intervals may be necessary. Steckling beds should be sprayed two or three times at two or three-week intervals, during the autumn, to prevent Virus yellows infection.

Mangold Fly (*Pegomyia betae*)—The mangold fly or leaf miner is a widespread pest of sugar beet. Well-grown forward crops can withstand quite severe attacks without appreciable loss of yield, but spraying is amply justified on backward crops, and when heavy infestations occur early in the season. Second generation attacks in July when the crop is well grown have little adverse effect and may be ignored, or controlled incidentally by methyl-demeton spray against aphis.

Spraying is recommended when plants in the 6–8 leaf stage are carrying more than 30 eggs and larvae in mid-May. A low volume spray of dieldrin, parathion, DDT or *gamma*-BHC emulsion will provide control, if applied at this stage. Under-leaf coverage is not necessary, and the insecticide will penetrate leaf tissue and kill maggots mining in the leaves.

CARROTS

Carrot Fly (*Psila rosae*)—This pest attacks carrots, celery, parsley and parsnips. Seedling carrots are destroyed or severely checked by the first generation, and infestations later in the season cause loss of yield and quality by mining the roots. Parsnip " Canker " and other rots are secondary infections of carrot fly damage.

The incidence of carrot fly can be minimised by sowing after mid-May, and growing the crop in open situations.

Gamma-BHC seed dressings provide good protection against first generation attack, and reduce the severity of infestations later in the season, and dieldrin seed dressings are also effective on light mineral soils. All carrot and parsley seed should be dressed as an insurance. Late attacks may be controlled by spraying two or three times during August and September with dieldrin emulsion in a high volume of water.

Application of aldrin dust or spray, immediately before preparing the seedbed, as for wireworm, often provides control throughout the season.

ONIONS

Onion Fly (*Delia antiqua*)—Onions are damaged throughout the growing season, by the maggots eating into the young plants and later into the bulbs, which are often rendered unfit for human consumption.

Control is obtained by dieldrin seed dressings or *gamma*-BHC dust applied along the rows at the " loop " stage.

SEED CROPS

Blossom Beetle or Pollen Beetle (*Meligethes aeneus*)—The adult beetles and the larvae damage the flower buds and feed on the flowers of cruciferous seed crops.

DDT, *gamma*-BHC or dieldrin sprays should be applied just before the flowers open. If spraying during flowering is necessary, harmful effects to beneficial insects may be reduced by spraying in early morning or late evening. All possible steps should be taken to exclude hive bees from the sprayed area, during operations and for a further 24 hours.

Turnip Seed Weevil (*Ceuthorhynchus assimilis*), **Turnip Seed Midge** (*Dasyneura brassicae*)—The turnip seed weevil

bores holes in the seed pods in order to deposit eggs. The larvae feed on the seed and pods.

Eggs are laid by the turnip seed midge in the holes bored in the pods by the weevils, and their larvae damage pods and seed in a similar manner but usually more seriously.

Spray just before flowering with DDT or *gamma*-BHC emulsion.

INSECTICIDES AND THEIR APPLICATION

Modern insecticides are all synthetic organic compounds of complex structure, as opposed to the older class of natural materials, such as nicotine, derris, and inorganic materials such as the arsenic compounds, which they have superseded.

Insecticides in use to-day fall into two main groups:—

CHLORINATED HYDROCARBONS

Insecticides in this group which are most widely used against farm pests in this country are:—

DDT, BHC (most commonly used as its *gamma* isomer), aldrin and dieldrin.

DDT—Is used extensively as a spray against beetle, weevil and caterpillar pests, and also against some species of aphids, mangold fly and leather jackets. Also used as a dust for many applications.

BHC—Is used mainly in seed dressings, and also in sprays and dusts with numerous uses for either foliage or soil application. Particularly useful against aphids, leaf-miners and wireworm.

Aldrin—Is widely used as a dust or spray or compounded in fertiliser, for controlling soil pests, particularly wireworms. If has the important characteristic of not inducing taint in potatoes or other crops at rates normally used. Aldrin is also used in seed dressings.

Dieldrin—Is a particularly safe and efficient insecticide for use in seed dressings. It is also widely used in emulsion form for controlling cabbage root fly, mangold fly and carrot fly, and as an alternative to DDT against beetle pests. It is less effective than DDT against caterpillars.

All these insecticides are relatively non-toxic and special protective clothing is not needed for their application.

However, care must be taken not to apply aldrin within three weeks, or dieldrin within six weeks, of harvesting crops for direct human or animal consumption.

ORGANO-PHOSPHORUS COMPOUNDS

This group includes some insecticides which come within the provisions of the Agriculture (Poisonous Substances) Act, on account of their toxicity, and Regulations are laid down for their safe handling and use.

Organo-phosphorus insecticides are used on farm crops principally for controlling aphids, particularly those species which are not adequately killed by DDT or where BHC and DDT are unsuitable. Some of these insecticides are also effective against fly pests such as mangold fly, and others will control certain caterpillars.

Parathion and TEPP—These are highly efficient contact insecticides, and TEPP has the special property of breaking down into innocuous material within a very short time of application. Thus it is valuable for use within a short time of harvesting an edible crop.

Malathion, "Dipterex," Diazinon—These are all compounds of low toxicity, and high efficiency against certain pests. They are recent introductions, which show considerable promise, and will probably be widely used when more is known about their performance.

Schradan and Methyl-demeton—These insecticides are systemic in their action, being absorbed and translocated within the plant, and thus they are persistent, and capable of killing aphids which feed on new growth which has developed since application of the spray. Schradan has very little contact action and is the more persistent of the two. Methyl-demeton has both contact and systemic action and is quicker in its action. It is also less toxic and no special precautions are necessary during its application, apart from when handling the concentrated material.

Note—Insecticide products vary considerably in concentration of active ingredient, and therefore manufacturers' directions for the use of their own products should be followed closely.

METHODS OF APPLICATION

SEED DRESSINGS

This is the preferred method of control, wherever it is effective or feasible, because of convenience, low cost, minimum risk of inducing taint in susceptible crops and destroying beneficial soil insects, and avoidance of mechanical crop damage by spraying and dusting machines. The cost of dressing seed is so small that it can well be regarded as a cheap insurance against possible damage or loss of crop by insect attack.

Seed dressings usually contain a fungicide, mercury being commonly used for protection against seed-borne diseases such as bunt and leaf stripe of cereals, and thiram or captan against foot rots and damping-off, which are soil-borne diseases.

The most widely used insecticides are *gamma*-BHC (lindane) and dieldrin, and also aldrin to a more limited extent.

The range of soil pests which may now be controlled by seed dressings includes wireworm, flea beetle, carrot fly, onion fly, bean seed fly, and, to a considerable extent, wheat bulb fly.

Maximum benefit from seed dressings is only obtained when all possible steps are taken to ensure quick germination and rapid seedling growth, by provision of adequate soil fertility, good seedbed preparation and efficient drilling.

The risk of seed injury should be guarded against by only dressing seed which is in good condition, and not storing dressed seed for longer than necessary before sowing. Care is also necessary to avoid possible damage by over-dressing, or poor pest and disease control by under-dressing.

SPRAYS

There has been a marked increase in the use of insecticides as sprays on farm crops in recent years, due to the greater availability of crop spraying machines, purchased primarily for application of selective weedkillers.

Most farm pests can be controlled by low or medium volume sprays and farmers who possess spraying machines find this method of controlling pests preferable to the use of dusts. The cost of insecticide and application is appreciably

less than for dusts, handling problems are reduced and application can be carried out more quickly.

Pests which move about fairly freely on plants and are reasonably well exposed to the spray can usually be controlled satisfactorily with a low volume application of 10–30 gallons of water per acre.

This applies to most of the beetle and caterpillar pests which are commonly encountered. With more static pests and those which occupy sheltered positions on the crop, such as black fly, cabbage aphis, pea aphis and midges, high volume application is necessary. It is advisable to increase the volume of water used as crops advance in growth and need more coverage, whether high or low volume spraying is being adopted.

In general, higher spray pressures are required for applications of insecticides than in the case of weedkillers, because different principles are involved.

Insecticide sprays can only function properly if they are correctly applied. Therefore, care should be taken to see that nozzles are working correctly, the spray boom is at the correct height, the intended output is being obtained and the spray pattern is correct.

It is now a common practice to apply soil insecticides in emulsion form by means of crop spraying machines. Application in this way is as efficient as dusts and appreciably cheaper.

If a crop spraying machine is used for applying insecticides following the use of " hormone " weedkillers, it is most important to clean the machine thoroughly to remove all traces of weedkiller which might injure susceptible crops. The following procedure is recommended:—

1. When spraying weedkillers always empty the spray tank at the end of the day, and then spray through with clean water plus wetter. Refill with water and leave overnight. It is most important to clean out machines immediately after use, and not defer the cleaning until they are required for further applications, or else, chemical deposits will set on the inside of the tank, etc., and are much more difficult to remove.

2. Before applying insecticides repeat the washing of the tank with water and wetting agent, and scrub the roof of the tank which is frequently not adequately cleaned by recirculation of water.

DUSTS

Although dusts have been superseded to a large extent by sprays and seed dressings, they still have their uses when spraying machines are not available or suitable for the purpose and when the use of seed dressings is not appropriate.

For treatment of farm crops low concentrate dusts consisting mainly of inert fillers are used. This is necessary to distribute evenly over a large area the small amounts of insecticide needed. Concentrations of dusts vary between 1 per cent. and 5 per cent. of insecticide. Soil insecticides are normally the lowest concentration because they are commonly applied broadcast with fertiliser distributors, many of which are incapable of applying evenly less than about $1\frac{1}{2}$ cwt. per acre. Dusts for foliage application which are applied with dusting machines at rates of 30–50 lb. per acre are usually a little more concentrated. Dusts for soil application have relatively heavy fillers, whereas dusts for treating growing crops need to be lighter and more evenly ground to ensure proper coverage of the crop foliage.

Another important development in the sphere of dry insecticide application, which is becoming extremely popular, is the incorporation of a soil insecticide in compound fertilisers. This technique is confined so far to the insecticide aldrin, and its main use is on potato crops. Combined insecticide/fertilisers are also suitable for combine drilling of crops such as cereals. The main advantage of a mixed product of this type is the elimination of an extra application, and also the insecticide is efficiently distributed owing to the large amount of " filler " employed.

Wherever possible avoid the application of insecticides to plants in full flower.

WEEDS AND WEED CONTROL

THE sight of weeds always conveys the impression of neglect, but there are many other reasons for keeping weed growth under control. Weeds cause serious reduction in yields by competing with the crop for light, plant foods and water; they make harvesting difficult—sometimes even impossible—especially in a wet year; they spoil grain samples; cause unnecessary work and cultivation—for example, the practice of bare fallowing to get rid of some of the more persistent arable weeds; weeds can also restrict the choice of crops to be grown because some crops are easily smothered by weeds and cannot therefore be grown in areas of heavy weed infestation.

In some cases produce is tainted by such weeds as wild onion and garlic; weeds often harbour pests and diseases of crop plants and create conditions favourable for plant diseases by preventing the free circulation of air round plants, thus making for greater humidity, which favours diseases such as mildew on peas and chocolate spot on beans.

Weeds in pastures and leys obviously reduce the grazing area for stock, but besides this some weeds, such as ragwort, may in certain cases be poisonous to animals.

CHEMICAL CONTROL

The use of chemicals for weed control has made rapid and spectacular progress since 1939, when virtually the only chemical weedkillers available were sulphuric acid and copper sulphate. Although all weed control problems are by no means solved, modern chemicals control most of the weeds in cereals, undersown cereals, grassland, leguminous crops, and in root crops if spraying is carried out before the crop emerges; in addition a chemical control is now available to kill couch on arable land. The rapid expansion of the spraying industry and the widespread adoption of spraying methods indicate spraying is a profitable operation.

CEREALS

The chemicals used for selective weed control in cereal crops are the two synthetic growth regulators, MCPA

(4-chloro-2-methylphenoxyacetic acid) and 2,4-D (2,4-dichlorophenoxyacetic acid)—known as " hormone " weed-killers—and DNC (2-methyl-4 : 6-dinitrophenol or 3,5-dinitro-*ortho*-cresol).

MCPA is at present the most widely used selective weed-killer; it controls most broad-leaved weeds in cereals, especially in the young stages of growth.

2,4-D kills a similar range of weeds to MCPA but has a much lower safety margin than MCPA and should not be used on spring oats.

Application—MCPA and 2,4-D are non-toxic and may be sprayed at low, medium or high volume. Cereals should not be sprayed during cold weather or when heavy rain is imminent, although slight rain following spraying will not reduce the effect.

The spray must not drift on to neighbouring fields of susceptible crops as it can cause severe damage and very great care must be taken to prevent drift in windy weather.

For the control of hormone resistant weeds, several promising new chemicals are undergoing field trials, but until more information is available about the new products DNC weed-killers will be used for most of this work.

Application of DNC—DNC must be applied at high volume using a machine with efficient agitation, capable of a pressure of at least 100 lb. p.s.i. It is a scheduled substance under the Agriculture (Poisonous Substances) Regulations and the precautions specified in those Regulations must be taken during spraying.

Timing—All cereals except oats may be sprayed from the five-leaf stage until the jointing stage, when the plant starts to run; oats may be sprayed very early, using MCPA from the one-leaf stage up to the time of shooting—the timing of DNC spraying of oats is the same as for other cereals. Most weeds are more easily controlled in their early stages, but a few should be sprayed at a later stage of growth (see Table 33 below). Consequently, to obtain maximum increase in yield the stage of growth of both crop and main weeds must be considered when deciding the timing of spray applications.

Several forms of these weedkillers are available commercially and rates of application vary according to the formulation of each product, but Table 33 gives an idea of the effect of each weedkiller on the more important corn weeds.

TABLE 33: WEEDKILLERS FOR CEREAL CROPS

Weed	MCPA	2,4-D	DNC
Bindweed (black) *Polygonum convolvulus*	Checks or kills young plants	Checks Kills seedlings	Kills young plant Kills top growth
Bindweed (lesser) *Convolvulus arvensis*	Treat at bud stage Tops and much of root killed	As MCPA	Kills top growth
Buttercup, bulbous *Ranunculus bulbosus*	Checks at bud stage	As MCPA	—
Buttercup, corn *Ranunculus arvensis*	Kills young plants	As MCPA	Checks or kills
Buttercup, creeping *Ranunculus repens*	Kills at bud stage	Severe check or kill	—
Charlock *Sinapis arvensis*	Kills all stages	Kills all stages	Kills all stages
Chickweed *Stellaria media*	Checks young plants	As MCPA	Kills seedlings
Cleavers *Galium aparine*	—	—	Kills young plants
Coltsfoot *Tussilago farfara*	Checks only	Checks only	—
Cornflower *Centaurea cyanus*	Kills seedlings	Kills seedlings	Kills
Corn gromwell *Lithospermum arvense*	Checks only	Kills young plants	Kills
Corn marigold *Chrysanthemum segetum*	—	—	Kills seedlings
Cranesbill *Geranium spp.*	Checks only	Checks only	Checks or kills
Dock, broadleaved *Rumex obtusifolius*	Kills seedlings	Kills seedlings	—
Dock, curled leaf *Rumex crispus*	Kills seedlings	Kills seedlings	—
Fat hen *Chenopodium album*	Kills seedlings Checks or kills young plants	As MCPA	Kills seedlings
Field mint *Mentha arvensis*	Tops killed Regrowth checked	Tops killed Regrowth checked	Top growth killed
Fumitory *Fumaria officinalis*	Checks severely or kills at young stages	As MCPA	Kills young plants
Groundsel *Senecio vulgaris*	Checks young plants	Checks young plants	Kills young plants
Hemp nettle *Galeopsis tetrahit*	Kills young plants	Checks only	Kills young plants
Hoary pepperwort *Cardaria draba*	Treat at early bud stage for 2–3 years; Top growth killed and some of root		—

Weed	MCPA	2,4-D	DNC
Horsetail *Equisetum spp.*	Kills tops and checks re-growth	As MCPA	—
Knawel *Scleranthus annuus*	Checks young plants	Checks young plants	Kills young plants
Knotgrass *Polygonum aviculare*	Checks young plants	Kills young plants	Kills young plants
Mayweed *Anthemis cotula*	Checks seedlings	Checks seedlings	Kills seedlings
Nettle, annual *Urtica urens*	Checks or kills young plants	Checks seedlings	Kills seedlings
Nettle, perennial *Urtica dioica*	Kills top growth	Kills top growth	—
Pennycress *Thlaspi arvense*	Kills all stages	Kills all stages	Kills young plants
Poppy *Papaver rhoeas*	Kills young plants	Kills young plants	Kills
Redshank (willow weed) *Polygonum persicaria*	Checks seedlings	Kills young plants	Checks young plants
Scarlet pimpernel *Anagallis arvensis*	Kills seedlings Severely checks young plants	As MCPA	Kills seedlings
Shepherd's needle *Scandix pecten-veneris*	Kills seedlings	Checks seedlings	Kills seedlings
Shepherd's purse *Capsella bursa-pastoris*	Kills young plants	Kills young plants	Kills young plants
Silverweed *Potentilla anserina*	Checks only	Checks only	—
Sow thistle (annual) *Sonchus oleraceus*	Checks young plants	Checks young plants	Kills
Sow thistle (perennial) *Sonchus arvensis*	Kills tops and some of roots if sprayed at 8 in. to flowering stage		—
Speedwell, birdseye *Veronica spp.*	Checks only	Checks only	Kills seedlings
Spreading orache *Atriplex patula*	Kills seedlings	Kills seedlings	Kills seedlings
Spurrey *Spergula arvensis*	Checks seedlings	Checks seedlings	Kills seedlings
Thistle (Creeping) *Cirsium arvense*	Kills tops and much of roots if sprayed at early bud stage		—
Treacle mustard *Erysimum cheiranthoides*	Kills young plants	Kills young plants	Kills young plants
White mustard *Sinapis alba*	Kills all stages	Kills all stages	Kills all stages
Wild carrot *Daucus carota*	Checks only	Checks only	Checks growth
Wild radish *Raphanus raphanistrum*	Kills young plants	Kills young plants	Kills young plants

CEREALS UNDERSOWN

In undersown cereal crops, the chemicals used for weed control are DNC (2-methyl-4 : 6-dinitrophenol or 3,5-

dinitro-*ortho*-cresol), DNBP (2-(1-methyl-*n*-propyl)-4 : 6-dinitrophenol or 2,4-dinitro-6-*sec*-butylphenol) and MCPB (S-(4-chloro-2-methylphenoxy) butyric acid).

DNC and DNBP may be used if the undersown seeds are drilled (not broadcast) and spraying takes place at least seven days before the grass and clover seeds are drilled, or during the three days following drilling. DNBP may also be applied once the clovers have developed two trifoliate leaves.

Application—DNC must be applied at high volume using a machine with efficient agitation, capable of a pressure of at least 100 lb. p.s.i.

DNBP should be sprayed at high volume, using low pressure, and agitation is not required.

DNC and DNBP are scheduled substances under the Agriculture (Poisonous Substances) Regulations, and the precautions specified in those Regulations must be taken during spraying.

MCPB may be used on all cereals undersown with grass and clover mixtures after the clovers have one trifoliate leaf; where the crop contains both red and white clovers it is important to make sure that both species have reached the trifoliate leaf stage. MCPB is safe on all cereals after they have two true leaves and before the jointing stage; grasses are unharmed by MCPB.

Application—MCPB is non-toxic and may be applied with any low-volume sprayer.

Several forms of these weedkillers are available commercially and rates of application vary according to the formulation of each product, but Table 34 gives an idea of the effect of each weedkiller on the more important corn weeds:—

TABLE 34: WEEDKILLERS FOR UNDERSOWN CROPS

Weed	DNC	DNBP	MCPB
Bindweed (black) *Polygonum convolvulus*	Kills young plants	Kills young plants	Kills seedlings Checks young plants
Bindweed (lesser) *Convolvulus arvensis*	Kills top growth	—	—
Black mustard *Brassica nigra*	Kills	Seedlings killed	Kills seedlings
Black nightshade *Solanum nigrum*	Kills seedlings	Kills seedlings	—

Weed	DNC	DNBP	MCPB
Bladder campion *Silene cucubalus*	Kills top growth	—	—
Buttercup, corn *Ranunculus arvensis*	Checks or kills seedlings	Kills seedlings	Kills seedlings Checks all stages
Buttercup, creeping *Ranunculus repens*	—	—	Kills to bud stage
Charlock *Sinapis arvensis*	Kills all stages	Kills all stages	Kills seedlings Checks young plants
Chickweed *Stellaria media*	Kills seedlings	Kills seedlings	—
Cleavers *Galium aparine*	Kills young plants	Kills young plants	—
Coltsfoot *Tussilago farfara*	—	—	—
Cornflower *Centaurea cyanus*	Kills young plants	—	—
Corn gromwell *Lithospermum arvense*	Kills all stages	Kills all stages	—
Corn marigold *Chrysanthemum segetum*	Kills seedlings	Checks only	—
Cranesbill *Geranium spp.*	Checks or kills seedlings	—	—
Creeping thistle *Cirsium arvense*	—	—	Killed or reduced if sprayed when 4–6 in. tall
Dock, broadleaved *Rumex obtusifolius*	—	—	Kills seedlings
Dock, curled leaf *Rumex crispus*	—	—	Kills seedlings
Fat hen *Chenopodium album*	Kills seedlings Checks or kills young plants	Kills seedlings	Kills seedlings and young plants
Field mint *Mentha arvensis*	Kills top growth	—	—
Fumitory *Fumaria officinalis*	Kills young plants	Kills young plants	Kills seedlings Checks young plants
Groundsel *Senecio vulgaris*	Kills young plants	Kills young plants	—
Hemp nettle *Galeopsis tetrahit*	Kills young plants	Kills young plants	Kills seedlings
Horsetail *Equisetum spp.*	—	—	Kills top growth
Knawel *Scleranthus annuus*	Kills young plants	Kills young plants	—
Knotgrass *Polygonum aviculare*	Kills seedlings	Kills seedlings	Kills young seedlings
Mayweed, stinking *Anthemis cotula*	Kills seedlings	Kills seedlings	—

Weed	DNC	DNBP	MCPB
Nettle, annual *Urtica urens*	Kills seedlings	Kills seedlings	Kills seedlings Checks young plants
Nettle, perennial or stinging *Urtica dioica*	—	—	—
Parsley piert *Alchemilla arvensis*	—	Kills young plants	—
Pennycress *Thlaspi arvense*	Kills young plants	Kills young plants	Kills seedlings Checks young plants
Plantain *Plantago spp.*	—	—	Kills if sprayed before flowering
Poppy *Papaver spp.*	Kills all stages	Kills seedlings	Checks seedlings
Redshank (willow weed) *Polygonum persicaria*	Kills seedlings	Kills seedlings	Checks seedlings
Scarlet pimpernel *Anagallis arvensis*	Kills seedlings	Kills seedlings	Kills seedlings Checks young plants
Shepherd's needle *Scandix pecten-veneris*	Kills seedlings	Kills seedlings	Checks seedlings
Shepherd's purse *Capsella bursa-pastoris*	Kills young plants	Kills seedlings	Kills seedlings
Silverweed *Potentilla anserina*	—	—	—
Sow thistle (annual) *Sonchus oleraceus*	Kills seedlings and checks young plants	Checks young plants	Checks seedlings
Sow thistle (perennial) *Sonchus arvensis*	—	—	Kills rosette; checks to flowering stage
Spear thistle *Cirsium vulgare*	—	—	Kills rosette and up to 4 in. tall
Speedwell, birdseye *Veronica spp.*	Kills seedlings	Checks seedlings	Checks young seedlings
Spreading orache *Atriplex patula*	Kills seedlings	Kills seedlings	Kills seedlings
Spurrey *Spergula arvensis*	Kills seedlings	Checks seedlings	—
Treacle mustard *Erysimum cheiranthoides*	Kills young plants	Kills young plants	Checks
White mustard *Sinapis alba*	Kills all stages	Kills all stages	Kills seedlings
Wild carrot *Daucus carota*	Checks growth	Kills seedlings	—
Wild radish *Raphanus raphanistrum*	Kills young plants	Kills seedlings	Checks only

GRASSLAND

The selective weedkillers MCPA (4-chloro-2-methylphenoxyacetic acid), 2, 4-D (2,4-dichlorophenoxyacetic acid) and MCPB (S-(4-chloro-2-methylphenoxy) butyric acid) are used to control weeds in permanent grassland and leys. Where clovers are present, MCPA and 2,4-D sprays may suppress their growth and these weedkillers should not be used on leys during the first year after sowing, but the newer herbicide, MCPB, is quite safe to use on leys and gives good weed control without depressing the clovers.

Application and timing—All three chemicals are non-toxic and may be sprayed at high or low volume any time during the spring and summer. Where grass is to be cut for hay, spraying should either take place in early spring (for buttercups, etc.) or be delayed until regrowth has occurred after mowing (for thistles, etc.).

The main grassland weeds are listed below with an indication of the effect on them of each chemical. Specific dosage rates cannot be given as they vary according to the formulation of the many commercial forms of these chemicals available.

TABLE 35: WEEDKILLERS FOR GRASSLAND

Weed	MCPA	2,4-D	MCPB
Burdock *Arctium spp.*	Kills; spray at rosette stage	As MCPA	—
Buttercup, bulbous *Ranunculus bulbosus*	Checks only; prevents flowering	As MCPA	Checks only
Buttercup, creeping *Ranunculus repens*	Kills pre-bud stage	Checks or kills	Checks or kills pre-flowering
Buttercup, upright *Ranunculus acris*	Kills pre-bud stage	Checks or kills	Checks or kills pre-flowering
Chickweed, mouse-ear *Cerastium vulgatum*	Checks or kills young seedlings	As MCPA	—
Cinquefoil, creeping *Potentilla reptans*	Checks or kills, spray before flowering		—
Cranesbill *Geranium spp.*	Checks	Checks	—
Daisy *Bellis perennis*	Checks or kills	Kills pre-flowering	—
Daisy (Ox-eye) *Chrysanthemum leucanthemum*	Checks	Checks	—

Weed	MCPA	2,4-D	MCPB
Dandelion *Taraxacum officinale*	Checks or kills spring or autumn	Kills spring or autumn	—
Dock, Broadleaved *Rumex obtusifolius*	Kills seedlings, checks established plants; old plants need repeated applications		Kills seedlings Checks established plants
Dock, curled leaf *Rumex crispus*	Checks severely or kills, spray before flowering		Checks or kills young plants
Field mint or corn mint *Mentha arvensis*	Tops killed Regrowth checked	As MCPA	—
Hawkbit, rough *Leontodon hispidus*	Checks or kills spring or autumn	Kills or checks	—
Hawkweed, mouse ear *Hieracium pilosella*	Checks or kills spring or autumn	Kills or checks	—
Hemlock *Conium maculatum*	Checks or kills; spray at rosette stage	As MCPA	—
Horsetail *Equisetum spp.*	Kills tops Checks regrowth	As MCPA	Kills top growth
Houndstongue *Cynoglossum officinale*	Checks only	Checks only	—
Knapweed *Centaurea spp.*	Kills rosette stage	Kills rosette stage	—
Nettle, perennial or stinging *Urtica dioica*	Kills top growth	Kills top growth	—
Plaintain, broad leaf or greater *Plantago major*	Kills all stages	Kills all stages	Kills if sprayed before flowering
Plantain, ribwort *Plantago lanceolata*	Kills all stages	Kills all stages	Kills if sprayed before flowering
Ragwort *Senecio jacobaea*	Kills or severely checks at rosette or pre-bud stage		
Rush, soft *Juncus effusus*	Kills May-July. If desired cut 4 weeks before spraying. Essential cut four weeks following spraying		—
Rush, hard *Juncus inflexus*	Checks only	—	—
Self heal *Prunella vulgaris*	Kills—spray before flowering	Kills—spray before flowering	—
Silverweed *Potentilla anserina*	Checks only	Checks only	—

Weed	MCPA	2,4-D	MCPB
Sorrel, common *Rumex acetosa*	Checks or kills	Checks or kills	—
Sorrel, sheep's *Rumex acetosella*	Checks or kills	Checks or kills	—
Thistle, creeping *Cirsium arvense*	Kills top and much of roots if sprayed at early bud stage		Killed or reduced if sprayed 4–6 in. tall
Thistle, spear *Cirsium vulgare*	Kills rosette stage	Kills rosette stage	Kills rosette stage
Yarrow *Achillea millefolium*	—	—	—
Yellow rattle *Rhinanthus minor*	Checks or kills when in active growth		—

PEAS, BEANS, CLOVER, LUCERNE AND SAINFOIN

The main chemical used for weed control in these crops is DNBP (2-(1-methyl-*n*-propyl)-4 : 6-dinitrophenol or 2,4-dinitro-6-*sec*-butylphenol); in addition, MCPB (S-(4-chloro-2-methylphenoxy) butyric acid) may be used on clovers and on the following varieties of peas: Alaska, Canner's Perfection, Dark-skinned Perfection, Harrison's Glory, Lincoln, Onward, Perfected Freezer, Rondo, Thomas Laxton, Servo and Zelka. MCPB is of most use in pea crops where the main weed is Fat hen (*Chenopodium album*) or Creeping thistle (*Cirsium arvense*).

Application and timing—MCPB may be used on red and white clover during the early stages of development, provided the clover seedlings have developed their first trifoliate leaf. MCPB may be sprayed on the varieties of peas mentioned above when they have between 3 and 6 true leaves, i.e., at approximately 3–6 in. tall. MCPB is non-toxic and may be applied through a low-volume machine at 20–40 gallons per acre.

DNBP may be used on most varieties of peas, although there are some varietal differences in susceptibility; field peas are most resistant, and peas for picking green are most liable to scorch. Peas should be sprayed when the crop is between 3 in. and 10 in. high; generally speaking, early spraying is advised as most weeds are more easily killed in their young stages.

On field beans DNBP may be used for weed control when the beans are about 3 in. high, while growth is still " hard " and before they grow away.

Lucerne, sainfoin and white clover may be sprayed with DNBP for weed control when they have at least two trifoliate leaves and red clover when it has at least four trifoliate leaves.

According to the formulation of DNBP used, it should be sprayed at medium or high volume; agitation is not necessary, and pressure should be as low as possible consistent with an even spray pattern. With some formulations of DNBP, dosage rate also varies according to the temperature at the time of spraying and the manufacturers' recommendations should be carefully followed.

DNBP is a scheduled substance under the Agriculture (Poisonous Substances) Regulations, and the precautions specified in these Regulations should be taken during spraying.

For the list of weeds controlled by DNBP and MCPB, see Table 34.

MANGOLDS, SUGAR BEET AND FODDER BEET

So far, only limited progress has been made with pre-emergent weed control in root crops, but extensive work on this problem has resulted in the discovery that some chemicals may be used for weed control as pre-emergent sprays. The most widely used chemical for this purpose is PCP (pentachlorphenol), but several others are available, including mineral oils, sulphuric acid, and potassium cyanate. These chemicals deal with broad-leaved weeds; it is also possible to control wild oats by spraying with TCA (trichloracetic acid) before sowing sugar beet (see page 240).

PCP will kill most annual weed seedlings which have emerged at the time of spraying, or which emerge a day or two after, including chickweed, redshank, fat hen, charlock, wild radish and knotgrass.

Application and timing—PCP should be applied at medium or high volume (over 30 gallons per acre). The timing of PCP spraying is most important as this chemical is not a selective weedkiller and must be sprayed after the crop has been sown and at least four days before it appears, as later spraying may result in crop damage. At the time of spraying the weed seedlings will be very small and often difficult to see, but if left untreated they grow quickly and

compete with the crop in its early stages when it is most susceptible to weed competition.

PCP is of comparatively low toxicity and is not a scheduled substance but reasonable care should be taken as it may cause skin irritation.

LINSEED

Linseed may be sprayed for weed control when the crop is 2 in. to 10 in. high using MCPA (4-chloro-2-methylphenoxy-acetic acid) or DNC (sodium) at high volume (about 100 gallons per acre). The varieties Dakota, Redwing, Royal and Valuta are rather more resistant than other varieties of linseed.

For the lists of weeds controlled by MCPA and DNC, see Table 33—although it should be noted that DNC (sodium) is rather less effective than the equivalent dosage of DNC.

FLAX

Flax may be sprayed for weed control when the crop is between 2 in. and 6 in. high, using either MCPA (4-chloro-2-methylphenoxyacetic acid) or DNC (sodium) at high volume (about 100 gallons per acre).

For a list of weeds controlled by MCPA and DNC, see Table 33, but it should be noted that DNC (sodium) is rather less effective than the equivalent dosage of DNC.

KALE

The pre-emergent technique of spraying—killing the weeds before the crop emerges—has been used with some success on kale, but as this is a quick germinating crop, accurate timing is essential. The chemical used is PCP (pentachlorphenol), which will kill most annual weed seedlings.

Application and timing—The method used is to prepare the seedbed and delay drilling for 10–14 days; this normally ensures the annual weeds appear 10–14 days before the crop and the spraying should take place 3–4 days before the emergence of the crop, using PCP at medium or high volume (over 30 gallons per acre).

CARROTS

It is possible to control many weeds in carrots using either proprietary selective mineral oils produced for the purpose or tractor vaporising oils. If vaporising oils are used spraying should not take place too late as this incurs the risk of taint and for the same reason thinnings should not be marketed after spraying.

Spraying should be at medium to high volume (40–80 gallons per acre) applied after the carrots have fully developed their cotyledons and while the weeds are still small. Spraying must be carried out before the carrots reach " pencil thickness."

CHEMICAL CONTROL OF COUCH GRASS

Until recently, the control of couch grass has been dependent upon summer fallowing, allowing the rhizomes to be dried out and killed. This method may be successful in a suitable season, but was ineffective in wet summers and always meant the loss of a crop during fallowing. More recently, repeated rotary cultivations have given effective control of couch grass, and the chemical weedkiller TCA (trichloracetic acid) has been shown to give effective control when combined with appropriate cultivations. The method is slightly different for light and heavy land. On heavy land, as soon as possible after harvest, cultivate to a depth of about four inches in August or September and apply TCA at 20 lb. per acre. During the next 4–6 weeks one or two further light cultivations to the depth of the original ploughing should be given and 4–6 weeks after the first treatment, another application of 20 lb. per acre TCA followed by one or two surface cultivations.

On lighter soils, spring application of TCA usually gives the best results, cultivating as early as possible in the spring, followed by an application of 15 lb. per acre TCA, one or two further cultivations and a second application of 15 lb. per acre TCA three or four weeks after the first treatment and one or two final light cultivations.

Crops vary in their tolerance to TCA and a suitable interval must be left following treatment, before planting; this period varies from four weeks in the case of potatoes, kale, turnips, linseed or rape, to twelve weeks for cereals.

WILD OATS

The most recent control method for weed grasses has been the use of TCA (trichloracetic acid) which, sprayed before sowing sugar beet, kale or peas, gives a control of wild oats.

Application and timing—TCA is readily soluble in water and may be sprayed at high or low volume using 7½ lb. per acre TCA. Spraying should take place about two weeks before sowing sugar beet, kale or peas and before the final cultivations are carried out. After spraying two or three seedbed cultivations should be carried out to mix the TCA throughly with the soil and bring it into close contact with the germinating wild oat seed—rotary cultivation is ideal.

CATTLE

BREEDS OF CATTLE

FOR some two hundred years the United Kingdom has been known as the "stud farm" of the world. It is not quite true to say that cattle have been exported to all parts of the world but at least some have been sent to all those countries where cattle are grazed. This has applied more especially to cattle of the beef breeds for it must be admitted that at first the dairy breeds were less well developed than the cattle we know as dual purpose. For many years dual purpose cattle held sway in the United Kingdom but during the present century they have been replaced by cattle of the pure dairy breeds at a surprising rate. Recent figures published by the Milk Marketing Board demonstrate these changes very clearly in the case of the census of cows in England and Wales.

Breeds or Types	1908 per cent.	1955 per cent.
Beef	15	16
Dual Purpose	83	27
Dairy	2	57
Total ...	100	100

What is more the total numbers have risen by 40 per cent. Yet another change has occurred even more recently, as may be shown by the following figures, which show a big reduction in the number of bulls for breeding:—

1940—92,000 bulls mated naturally to 2,750,000 cows.
1950—95,000 bulls mated naturally to 2,250,000 cows.
700 bulls mated to 700,000 cows by A.I.
1955—65,000 bulls mated naturally to 1,500,000 cows.
800 bulls mated to 1,500,000 cows by A.I.

It is quite well known that A.I. (Artificial Insemination) is increasing in popularity, so the number of bulls retained for breeding will continue to fall for a time. There will also be a continuing change in the breeds kept to meet the

public demand because of the relative profitability of the cattle products—beef, butter, cheese or milk. From time to time the numbers of cattle in the various breeds are subject to considerable variation and at first sight there seems little point in giving them in detail, but it may be worth while indicating the order of their importance to-day since this order may persist for some years. In 1957, milk surplus to the needs of the liquid market was produced and in consequence some went for manufacture. If this continued for any great length of time it may lead to certain breeds becoming more popular if their milk proved more profitable for processing. At the present time the British Friesian has a clear lead over the Dairy Shorthorn with the Ayrshire lying third, but a sudden demand for milk for butter making would lead to increased numbers of cows of the Channel Island breeds being kept.

Before the breeds are considered in detail another change must be mentioned, namely, the fact that horns have become unpopular. Breeds once horned are now breeding pure without horns, whilst others with horns have them removed by artificial means. This change, which has arisen because horns so frequently lead to injuries, has come about more slowly in this country compared with overseas.

DAIRY TYPE

In general appearance a cow must look feminine and be of fine quality with no suggestion of coarseness in skin, hair or bone. The dairy cow should have three recognised wedges. The first made by the top line with the under line seen by standing broadside on to the cow. The second is formed by the width of the chest leading vertically to the point of the withers, whilst the third is seen by standing just behind the cow and looking for the triangle made by the hooks leading to the withers. The last general point to be considered, some would put this first, is that a cow must show promise of good mammary development.

These points can be described in greater detail. The length of the face should be long, with a broad muzzle. With some breeds width between the eyes is desirable, but in others it is not very important. For all stock a bright eye is essential as an indication of good health. Neither ears nor horns (if present) should be coarse. Wrinkling of

the skin on the face or neck indicates a thin skin, which is needed for quality. The necks of all dairy cows should be long and lean, with no suggestion of heaviness of brisket, which is a characteristic of beef types. The neck must be neatly joined both to the head and also to the shoulders, the latter being clearly seen without undue coarseness. Fineness of shoulder will usually produce narrowness at the withers, which is essential. The front legs must be well placed, with the feet close together when the cow is standing quietly. The legs afford another chance to look for coarseness of bone, since there is very little more than bone on the front leg below the knee. The shoulders should lie close to the body. Since the dairy cow must consume large quantities of bulky foods, a large body is essential. Capacity is produced by depth immediately behind the shoulders, still greater depth just in front of the udder and width of barrel and chest. Thus, there is plenty of room for heart, lungs and digestive system. The hind quarters are usually considered to be the business end of the cow for the skeletal framework supports the mammary system. For this purpose there must be a large pelvic girdle made by width between both hooks and pins and also by length between the hooks and the pins. Good legs must be placed well apart (to allow plenty of room for a full udder) with thin thighs that are not fleshy. Mainly for appearance sake, the tail should be on a level with the top line. A high, coarse tail setting is not only unsightly but in some instances may interfere with natural breeding. The thickness of the tail may also indicate coarseness. The udder should extend well forward along the belly and also well up towards the tail. There should also be width throughout to give plenty of capacity. A pendulous udder is not merely a bad show point, for experience has shown that such udders are more prone to injury when cows are walking and consequently there is a greater risk of trouble than when the udder is of normal shape. Although the udder consists of four separate quarters they should be uniform in size and so moulded together, that the separate parts cannot be seen from any angle. The tissues within the udder must not be fatty (or fleshy) but only by experience can this be ascertained by touch. The right texture is observed when the udder shrinks appreciably in size during milking and swells again in time for the next milking. All

the quarters should be of the same soft texture and any heaviness in one of them must be viewed with suspicion. There should be four (and only four) well-placed teats of the right size to make hand or machine milking easy. Running forward from the udder are the milk veins, usually one on each side of the belly but there may be more in better cows and where they suddenly turn and run into the belly the milk wells are produced. These should be large and at least two in number.

A good cow has plenty of fine silky skin everywhere, but especially on the udder and over the ribs. A heavy hide which handles badly, being harsh and dry, may indicate sickness.

These points should be seen in heifers and calves and the same general type also in bulls, though the male characters will somewhat mask the quality seen in the cows.

BEEF TYPE

This type is clearly shown in the diagram which gives the positions of the various cuts and the names of various parts known to the farmer (Fig. 21, page 280). A beef cow must be beefy, no matter from what angle she is viewed. This is called blockiness, which can only be obtained by the top line being parallel with the under line and by a squareness that is clearly seen when standing immediately behind. Squareness must start at the fore end and be continued right to the hind end. Since bone is only needed to support the cow and to provide something around which the meat is built it is evident the finer the bones, the better pleased will be the butcher, since consumers wish to buy joints with relatively small percentages of bone to meat. For slimming diets consumers do not want very fat meat, hence from the butchers' angle the stock must not be excessively fat, least of all should they show signs of producing patchy fat.

A beef head is short and broad. Width is needed in both muzzle and between the eyes, whilst the neck should be short and thick with what is known as the neck vein, well filled with meat. This means the shoulders are so well hidden they cannot be seen and it is essential to handle the cow to discover the exact position of the points of her shoulders. The shoulders are set wide apart (the exact opposite of the

dairy cow) and if the cow is well fleshed the front legs will be forced wide apart. Also in the case of a very fat beast the front legs may be so far apart that a man can crawl between them. Extending between the forelegs is the brisket. This is not valuable meat, but is taken to indicate ability to put on flesh and, for that reason, a good broad brisket is popular. Immediately behind the shoulders are the ribs, which should be so well sprung there is no depression immediately behind the shoulders. This spring of ribs should be continued right to the loin and to the hooks. In a good cow the loin is so hidden it is impossible to see where ribs end and loin begins. A beef cow must have a depth of barrel right from the front legs to the loin, for a shallow animal lacking in spring of ribs will not have the essential good joints of meat. The hooks are less prominent than in the dairy cow but this does not mean they should be narrow, for it is just behind the hooks where the valuable rump steak is found. Thus, length from hooks to pins is also important, since this also allows room for the rump. The fleshing must extend well down the leg no matter whether viewed from the back or side. When viewed from behind the flesh on the inside of the thigh is known as the twist, which, even in the case of the beef cow, is large and allows very little room for her udder. The flank, although it is not the best quality meat, should be thick and low, since that is taken to indicate fleshing in other parts of the animal. The udder is of necessity small, for it is only required to produce sufficient milk to rear the cow's own calf. Thus, the udder is almost ignored in the case of the beef cow. Whilst the hind legs of the dairy cow are forced apart by the udder, in the beef animal they are forced apart by the flesh that lies between the hind legs. Thus, both front and hind legs of the beef cow are far apart.

The younger heifers are simple miniatures of the older animals and display the beef type in much the same way as their dams. The bulls also show beef type. The character in which they may fail is in the coarseness of bone and, in some breeds, in thickness of the skin. None of the beef breeds have such fine skins as are found in the dairy breeds. This is to be expected because the beef breeds have often been bred to live under hardy conditions, being out of doors all the year round.

Beef type cannot be left without special mention being made of what the butcher requires in a bullock that is ready for slaughter. Essentially he needs a well-fleshed animal (the degree of fatness will depend upon the trade he caters for, as will also the size) with plenty of meat where the most valuable cuts lie, namely, along the back and at the hind end. There must be no excess of fat anywhere and excess over the pins or tail is looked upon with disfavour. When feeling for evenness of fleshing the hand should be run over the ribs, over the loin to the flank and finally to discover the extent of the deposit of fat in the cod (or purse).

DUAL PURPOSE TYPE

Dual purpose cows must produce both meat and milk, so it is not surprising they look like dairy cows in some respects and yet carry some flesh as would beef. They have the three dairy wedges less pronounced than in dairy cows. The top line and under line should produce wedges quite as good in the dual purpose cow. A dual purpose cow usually carries more flesh than its dairy counterpart and this is most apparent during the later stages of pregnancy and shortly after calving, but in the case of the better milkers some of this flesh is lost during the lactation, whilst the poorer milkers retain their flesh. As a general rule, dual purpose cows do not show the same quality as evidenced in the pure dairy type. They are usually heavier in their skins, which means less wrinkling, and the bones are usually thicker.

Conformation need not be discussed in detail, since the dual purpose cow is essentially a dairy cow with a fairly uniform covering of flesh over her body and between her bones. For instance, where her shoulder blades lie over the ribs there will be fleshing which gives width over the withers. The mammary development in the dual purpose cow is slightly different in appearance because there is more fleshing, which may lead to excess of fat in the udder, and this may take up space that should be occupied by mammary tissues. Thus, special care must be taken when judging the udder to feel the mammary glands. This is difficult when the udder is full of milk, so it may be essential to handle immediately after milking. The right type of tissue is spongy and shrunken after the milk has been removed,

whereas the wrong type is large, inelastic and heavy to handle. It is also possible, after milking, to examine the udder for uniformity of quarters; this may be missed if the udder is full of milk. With an empty udder it is possible to see the amount of loose skin present to judge how much room there is for the udder to become distended when the cow is in full milk. The veins both on the udder and those leading from the udder are less prominent in the case of the dual purpose cow, compared with the dairy cow. The milk veins are also somewhat masked by the thicker skin and the extra fleshing of the dual purpose animal.

The dual purpose cow herself must be a milk producer and, in the case of most of the breeds, be capable at maturity of producing 1000 gallons of milk per lactation. When her milking days are over she must produce a respectable carcase of meat. The daughters must be comparable whereas the sons, if not retained for breeding, should be suitable for meat production at various ages, namely, at three months for veal, fifteen months for baby beef and (at the present time) for mature beef as near to twenty-four months as possible. Any heifers not suitable for the dairy herd should also make good beef at the same or slightly younger ages.

Dual purpose bulls are always more difficult to judge since they must of necessity carry a certain amount of flesh to show they are thrifty and in consequence it is difficult to judge the real dairy type. It is far better to judge bulls upon production rather than type (namely upon the milk yields of their dams) and even better still, on their daughters if they are old enough to have any heifers that have completed lactations.

DAIRY BREEDS

It is generally recognised that there are five dairy breeds kept in this country:—Ayrshire, British Friesian, Guernsey, Jersey and Kerry. Some may question the inclusion of the British Friesian and also the Kerry in this category since under certain circumstances they will produce beef.

Ayrshire—The Herd Book was first published in 1878. The animals are predominantly white, with either a little brown or black. Occasionally there may be an almost

brown animal, but seldom a pure black. Formerly the horns were prominent with an upward turn, but in many herds they are now removed at birth, or later and some strains are hornless, that is, they are breeding true as polled stock. The breed is famous for several marked dairy characteristics, namely, (*a*) the pronounced dairy wedge arising from the fine shoulders and withers, (*b*) the shapely and compact udder, and (*c*) the uniformly, well-placed teats that are now large enough for efficient machine milking.

The milk yields from mature cows are second highest of all breeds in the United Kingdom, whilst butter-fat percentages are usually just under 4 per cent. The fat globules are small and hence the milk is very suitable for cheese making. The breed is hardy and forages well, thriving on some of the poorer exposed land. Ayrshire breeders were pioneers in the development of sales of attested heifers and in consequence the breed spread to many parts till at present nearly 20 per cent. of the cows in England and Wales are Ayrshires. During the last few years the emphasis on beef has reduced the rate of spread, but it is interesting to report that in some of the dairying districts the cows are crossed with Herefords, using A.I., and the cross calves when reared for beef are said to be quite satisfactory. As a breed they can have their first calves when two years old, without detrimental effects upon subsequent growth and milk production.

British Friesian—This breed was imported from the Friesland area of Holland on many occasions during the last 200 years. In the early days there was no attempt to keep the breed pure and it is claimed it played a big part in the development of the Shorthorn, as milk producers. The British Friesian Cattle Society was formed in 1909 and organised importations from Holland, South Africa and Canada. Normally the breed is black and white in whole colours, but there is a special sub-section of the breed where the cattle are red and white, being selections from the black and white cattle. Formerly this breed carried small incurving horns, but now many are dehorned and some herds are breeding true as polled stock. The mature cows are the largest of the true dairy breeds. They have large frames and barrels and the udders are large, sometimes exceptionally so, with very prominent milk veins and wells.

During the last 20 years national policy has placed greater emphasis upon milk production, with the result that the Friesian has spread very rapidly because of the high individual milk yields that can be obtained. No other breed can compete with the British Friesian for quantity of milk produced. As a result the quality, as shown by both the butter-fat percentage and also the solids-not-fat, sometimes falls below the legal minimum allowed (fat, 3 per cent., and solids-not-fat, 8·5 per cent.). The fat globules of the milk are small, thus making it very suitable for feeding to babies. Since the breed produces large cows they are hearty feeders and need liberal supplies of good grass and, when housed, they make good use of liberal supplies of concentrated foods.

As a result of the high milk production, this breed has outstripped all others; over 40 per cent. of dairy cows in this country are Friesians.

The calves are well-fleshed when born and any bull calves not required for breeding are quickly turned into good veal: they are very popular for this purpose on the Continent. In recent times the breed has proved very suitable for producing the leaner bullocks the British meat trade is now demanding. The bullocks are in good condition for killing when about 2½ years old.

Guernsey—Guernseys have been bred pure for centuries in the Channel Islands, where no imports have been permitted for a long period. The English Guernsey Cattle Society was formed in 1884. Imports into this country have continued more or less regularly for well over 100 years. The latest figures show only just over 5 per cent. of dairy cows of this breed, but in some areas, namely the Isle of Wight, Cornwall and Surrey they constitute one-third of the dairy cows kept. The breed is typically of dairy type with quality showing up prominently in the skin and usually in the bones, though occasionally the tail heads are inclined to be a little coarse. The colour is primarily fawn and brown with varying shades between those colours, with sometimes white patches. The end of the tail is often white, while the nose is usually pink, black being most unpopular. The skin is highly pigmented and yellow in colour as also the milk, which is rich. The fat globules are large and the milk very suitable for the cream trade or for butter. The

yield of milk is not as high as that from the previous breeds but when the butter-fat production is calculated Guernseys give as much butter-fat in a year as do British Friesians. Thus, for butter or cream, this breed must be given serious consideration.

Guernseys are the more hardy of the Channel Island breeds and thrive in much more exposed conditions than many would expect. They usually have their first calves when they are about 2½ years old.

The breed is sometimes criticised because the udders tend to be pendulous and not carried well forward along the body.

Jersey—The Jersey, also originating in the Channel Islands, is quite different from the Guernsey in a number of respects, though having some very definite points of similarity. Jerseys have been bred pure for 200 years and were sent into England and Wales for many years before the English Jersey Cattle Society was formed in 1897. The breed is famous for quality, exemplified both in appearance and in the quality of the milk. The skin and bones give the best examples of quality found in any breed of cattle native to the British Isles. Stock born on the Island of Jersey usually show more refinement than those born in England and Wales.

The breed is inclined to be tender and whenever cattle are imported from the Island they need special care and are often rugged when grazing. The colours range from greys almost to whites and from dark brown to whitish fawn, being shaded and lighter on the underside of the belly and the inside of the legs. The tail and the tip of the nose are usually black.

The general appearance is that of a true dairy animal, for the dairy wedges are very definite, the cows carrying very little flesh. The bones are very easily seen and on the neck the veins show through the thin skin. This thinness of skin has some effect upon hardiness, for this breed is the most tender of all British breeds. Jerseys do very well in the hot sub-tropical places. This is one of the smaller breeds which is very efficient in the production of milk when allowance is made for live weight. The barrel is often relatively large in proportion to the rest of the body. Udders are inclined to become pendulous with advancing years, but at the heifer stage are held neatly and close to the body. Jerseys produce

richer milk than that from any other dairy breed. The yield of milk is not so high as that of other breeds, but when food consumption is considered the efficiency of milk production is high. The milk is richly coloured, has large fat globules and is most attractive when placed in bottles for the retail trade. Heifers calve for the first time when only 18–21 months; this is younger than any other breed found in this country.

The meat value of the breed is very low, but in New Zealand the breed is being crossed with the Aberdeen Angus for the production of meat, with apparently good results. One disadvantage of using the Jersey for meat is that the fat is rather yellow in colour and to some people somewhat unappetising.

Kerry—The Kerry comes from Ireland and not from the area in Wales of the same name. The breed is a very old one but it has not spread much into other counties. At the present time there are only several hundred cows in the whole of England and Wales.

The breed is usually entirely black, though occasionally there may be white patches on the udders of the cows. The horns are relatively large and upturned. The general appearance is that of a typical sparsely fleshed and angular dairy cow yet some authorities regard the breed as dual purpose. The udders are usually pendulous in the mature cows. The bone of the whole animal is fine and gives the effect of quality, although the skin is never so fine as that found in the Channel Island breeds. The heavier skin and plentiful hair gives hardiness.

The breed will live and milk well in rather exposed areas and on poor grass and roughages. When one considers the poor nature of the food supply the average yields are high, for they are often 600–700 gallons of milk containing nearly 4 per cent. butter-fat.

BEEF BREEDS

The recognised beef breeds of this country are Aberdeen Angus, Devon, Galloway (including the belted breed), Highland, Hereford and Shorthorn. Whereas there has been relatively little export of the dairy breeds from this country, rather more from some of the dual purpose breeds, almost all the beef breeds have been widely exported to many parts of the world. This trade in beef cattle overseas

started some two hundred years ago and still continues with such high prices that the overseas demands dictate the breeding policy pursued by the leading breeders of practically all of the beef breeds in this country. In consequence, the home market often only receives secondary consideration. The overseas demand is for small beasts with very thick-set bodies and fine bones on short legs. In this country, beef bulls for crossing with the dairy and dual purpose breeds should not be the very small, short-legged type but larger and of the real beef type.

Aberdeen Angus—The Aberdeen Angus has been developed in that part of the East of Scotland which has given it the name. This black, polled breed is famous for a beefy type of body with blockiness, no matter from what angle viewed. It is renowned for fine bones, in fact leg bones appear to be too fine to support the compact meaty bodies. Quality is abundantly apparent in skin, bone and evenness of fleshing which is characterised by the absence of any patchy fat over ribs, loins or rumps. The breed has been used for crossing with dual purpose Shorthorns in both Scotland and Ireland to produce stores for commercial beef production. When mated with the white Shorthorn the progeny is grey, often known as "blue greys." There is a big demand for these greys as stores to go to the arable areas of the North of England and to East Anglia for fattening in yards. The Aberdeen Angus is better suited for fattening in yards than at grass. It is well recognised that the breed produces meat of excellent quality, but the criticism of feeders is invariably that whilst butchers like the quality of the Aberdeen Angus they are not prepared to pay an adequate price. Thus, some feeders find the breed does not pay as well as some of the larger breeds, since quality does not command a sufficient premium.

The Aberdeen Angus has been widely used for sires at A.I. centres for crossing. The calves are black and as a general rule polled, no matter the breed with which they are mated.

Devon—The Devon, sometimes called the "Devon Ruby," to distinguish it from the lighter-coloured South Devons, is also often called the North Devon for the same reason. This latter name shows the area from which they

come, the breed being developed in the exposed areas of Exmoor and other parts of North Devon. They are certainly a hardy breed and usually dark red in colour. The conformation, whilst undoubtedly of beef type, is more leggy and lacks in development of the hind leg when compared with some of the other beef breeds. They grow quickly as calves and make very good live weight gains when still under two years of age. Here is a breed that meets the modern requirements better than most, since they are not too large even at maturity and when well managed, will be fat when weighing no more than 10 cwt.

An interesting aspect is that this breed is sometimes kept for milk production and in the past cows have appeared at the London Dairy Show. The milk is rich and is often separated for the production of cream for sale as clotted cream.

The Devons are an old breed for the Herd Book was first published in 1850.

Galloway—There are two sections to the Galloway breed, but the only difference lies in the colour marking and not in conformation or meat-producing ability. Galloways are black or a kind of brown, or dun, in colour with usually no white. The belted section of the breed is basically black, or dun, with a belt of white running around the barrel, usually between the legs. Thus, most of the barrel is white. Both breeds have heavy skins and coats which are usually shaggy or curly. From now onwards the two breeds are to be treated as one. The general conformation is blocky but not quite so compact as some other breeds. There is a lack of spring of ribs which reflects in the amount of fleshing on ribs and loin. The bone is not so fine as in some breeds, but it is not at all coarse. The head is short, in fact the shortest of any of the beef breeds.

While the cows breed and calve out of doors in very exposed places, the steers are often fattened indoors in the old-fashioned way. The steers have a good reputation with butchers, since they kill out at a good percentage and the proportion of lean to fat meat is excellent. In the past Galloways have often won carcase competitions because of the excellence of their meat. The breed is somewhat slow in maturing and no one would attempt to fatten steers at a young age. When mature, the steers produce joints that

are the right size for modern requirements and if only they grew a little more quickly the breed would be ideal.

Hereford—Although this breed was developed in the county which bears the same name, at the present time it is found more widely dispersed over the British Isles than any other of the beef breeds and this is often at the expense of the local breeds. This is a fitting testimonial to the excellence of the breed under a wide range of climatic conditions and food supplies. Not only is the breed found pure, but it is also crossed with a number of other breeds. The wide use for crossing arises from the dominance of the beef type and the characteristic colour of deep red except for a white head, top line, sometimes under line and white feet. The colour marking seems particularly dominant on the face and head. Pedigree breeders prefer a deep red colour but lighted reds are seen. A possible failing of type lies in the heaviness of briskets and the resulting heavy fore end. Sometimes the skin is rather thick which leads to a low killing out percentage; hence their title from butchers, "white faced robbers." The other failing sometimes considered serious is the tendency to get patchy fat, especially as heifers, but if killed in time this should not arise. The breed has two very important characteristics. In the first place Herefords grow freely when young and they fatten well, with the result they may be fat at 15 months, or at 2 years, or if allowed to grow on they make good beef at 2½ to 3 years. Secondly they are excellent grazers and fatten readily at pasture. For this reason they have been very popular for the export market.

The breed is normally horned but the present demand for polled stock has resulted in a special importation of polled Hereford cattle into the United Kingdom in 1957. This is probably the first (and possibly last) importation of pedigree beef cattle into this country.

Highland—Highland cattle are known to all, if for nothing else than their picturesque exteriors and background. The breed lives in cold exposed areas of Scotland where the food supply is such that no other cattle could survive, the other stock in the locality being mountain sheep. These hardy cattle are of all shades of brown from the dark, which is almost black, to a light sandy colour. They have

such a thick shaggy coat that it entirely envelopes them, including their faces, and they frequently have difficulty in seeing.

The wide expanse of horns prevent them being housed at any time during their lives. Not only have they a thick coat, but also a thick skin and lack in some beef characteristics, being flat-sided with poor development of their hind legs.

Highland cattle have not spread far from their natural habitat, but in Scotland have been used for cross breeding, often with the Shorthorns, to produce hardy steers for outdoor fattening.

Shorthorn—Some refer to these Shorthorns as Beef Shorthorns, though this is not necessary for the original Shorthorns were beef animals. The breed was developed in both the North of England and also in Scotland, but to-day is looked upon as a Scotch breed, since the important sales of the best Shorthorns for the export trade are held in Scotland. It has been exported to the chief grazing areas of the world for the breed is dominant when crossed with native stock. White Shorthorn bulls are often mated with black Galloway cows to produce the famous Blue Greys that are much sought after by graziers and fatteners. The normal colours of the Shorthorn breed are red, white and roan, but the red and white in whole colours are not favoured. The only colour not wanted is black and should it occur on any part of the beast it is looked upon with disfavour.

Shorthorns afford an excellent example of beef type for they are blocky, with well-sprung ribs giving them an appearance of solid meat. They have short heads, thick necks, and often very short legs. This latter point is keenly sought after by buyers for export. The breed is very quick growing and may be fattened at almost any age according to requirements. The fleshing is usually good but there is just a tendency to produce slight patchiness over the hooks and the pins. This is most likely to appear in older cows kept for breeding.

The cows of this beef breed, like many other of the beef breeds, often produce insufficient milk for their own calves. Hence, the practice of supplementing the dam's milk with that of a foster cow (or a nurse cow) is very common, where the bulls are being reared for show and sale and where the

breeders are anxious not to exert too great a strain upon the pedigree dams.

Sussex—Sussex cattle have been developed from the South Downs and the clays of Sussex. This breed is invariably deep red in colour and is very similar to the Devon in many respects, namely colour, size, horns, rate of growth and grazing ability. Sussex are the very best grazers for they do not discriminate; they eat all that grows so they are just like "living mowing machines." This makes them most useful for feeding as stores or for final fattening out of doors. This grazing habit has also made them popular overseas where they have been purchased solely as grazing stock.

They may be criticised a little from a beef point of view, since there is a tendency to legginess and they may lack meatiness on their hind legs. It may also be that since they carry very thin coats they appear worse than they really are.

In the United Kingdom the breed has spread very little outside its natural breeding area, although at one time it had a name for the excellence of the steers for work.

DUAL PURPOSE TYPES

The dual purpose breeds are: Dairy Shorthorn and Lincoln Red Shorthorn, Dexter, Red Poll, South Devon and Welsh Black. There are also the British White and Blue Albion which are in such small numbers that they may be ignored; nor is it likely that in the near future they will play a big part in the milk or beef supplies of this country.

Dairy Shorthorn—It must be readily admitted that this type of Shorthorn was developed after the beef breed had been recognised; even so, it became a definite breed in 1905. At one time the Dairy Shorthorn produced the bulk of the milk for the liquid market in this country. One of its characteristics, therefore, is adaptability since it is found in almost all parts of the British Isles. The breed may be of various colours, red, white and roan, in fact a wide range of these colours, but not black or grey. Although the breed had small incurving or slightly upturned horns, with the present trend, the horns are disappearing. The dairy wedges are usually good for a dual purpose animal for there is, as might be expected, a tendency to have heaviness at

the shoulders and especially at the withers. The udders are variable but often well shaped and carried close to the body. As with all dual purpose breeds they incline to fleshiness. This is also a typical beef-producing animal for beef may be produced from the steers at all ages according to the feeding policy pursued. In addition, the non-breeding heifers are easily turned into beef, whilst cows at the end of their milking days can be sold fat.

Although one might form the impression that Shorthorns do not milk well it should be pointed out that in the national averages they are usually third for quantity and there is always one, and sometimes two, breeds below them for the butter-fat content of their milk.

Lincoln Red Shorthorn—The Lincoln Red Shorthorn is a definite breed and was developed from the Shorthorns. The Herd Book dates from 1893, but later joined up with the Shorthorn Society for a time and then finally separated in 1941. In 1946 it was divided into beef and dairy sections. As might be expected, the animals are wholly red, and white is not permitted. The breed has been developed in Lincolnshire where liberal food supplies are available and thus, over a period of time, it has become one or two hundredweights heavier than the stock from which it originally sprung. This extra weight arises from a bigger frame and a tendency to coarseness. Also the skin is usually heavy and since the hair is abundant it makes the cows look heavier than they really are. The milk yields are no higher than those of the parent breed, while the butter-fat is usually just a fraction higher.

Lincoln Red herds are seldom seen outside Lincolnshire, but the breed plays a very important part in the beef world, since bulls are much in demand for crossing purposes at the A.I. Centres in the Midlands. The breed not only colour marks the progeny but also passes on the characteristics of good beef types. The breed is hardy and makes excellent graziers. Moreover, it grows quickly and whilst it could be developed for young beef it plays its most important rôle in producing mature beef off grass, by which time the bullocks often weigh 15–20 cwt. when about three years of age. Such heavy-weight beef is not in great demand to-day and the pure breed may have to adjust itself to produce smaller,

fat animals at a younger age. The cross can be more easily adjusted.

Dexter—The Dexter is the smallest breed of cows found in this country and has often been so rightly described as Shorthorns seen through the wrong end of a telescope. They are, in fact, miniatures of the Shorthorn type. There is one main way in which they differ from the Shorthorn, namely in their colour, which may be red or black but not white, or the mixtures of red and white that are called roan in the case of the Shorthorns. This breed springs from Ireland and was at one time rather mixed up with the Kerry, though they are of quite a different type. The Dexter has also been developed in a district with rather poor food supplies, hence they are good foragers. One outstanding characteristic is their shortness of legs which made milking difficult, until two-level milking platforms were introduced. The udder is inclined to be pendulous and the teats are often relatively large. The milk yield is large for the size of breed since over 500 gallons containing over 4 per cent. butter-fat may be a common herd average. Steers make good mature beef as also do crosses of the breed. Carcases are small as are needed for public taste to-day.

Red Poll—The Red Poll was developed in East Anglia, partly in Suffolk and partly in Norfolk. They are still found in quite considerable numbers in those counties, having poor sandy land, though they have spread to a limited extent to other areas. There is a danger that when the breed passes into other areas it becomes coarse in bone should food supplies be plentiful. The colour is red (preferably deep red) whilst conformation is typically dual purpose, with the exception that the cows often lack depth just in front of the udder which means that one of the dairy wedges is often not well pronounced. They have been described as a drain pipe on four legs. There is another criticism, the mature cows often have very pendulous udders because they are not attached well along the belly. Yields of milk and butter-fat are usually a fraction below those of the Dairy Shorthorn. So far as beef goes the Red Poll calves grow very freely and are ready for slaughter when 12–18 months of age making baby beef. As mature beef they tend to lack development at the hind end.

South Devon—The South Devon was developed as a dairy breed in the county from which they have taken their name. They are the largest of the breeds found in the British Isles; this being no doubt the outcome of the plentiful supplies of grass they obtain in their native countryside. The breed is lemon red in colour, or fawn, but there must be no white. The cow has a large bony frame which is sometimes coarse at the tailhead. Heads are long and heavy. The breed is related to Channel Island Breeds for they have some of the typical colouring found in the breeds of those islands. The large udders are often somewhat pendulous and the teats large and coarse. This breed produces milk richer in butter-fat than that produced by any other dual purpose breed, being usually well over 4 per cent. The milk is highly coloured with large fat globules similar to that of the Channel Island Breeds. It is this breed which has been largely responsible for the trade in the famous Devonshire cream. A subsidiary to that trade has been the rearing of the calves for beef production upon the skim milk. Thus, on the small farms of Devonshire many calves were reared till they were yearlings (and in some instances retained till they were ready for sale for fattening when about two years old) when they go into the grassland areas, principally of the Midlands, for fattening in the summer on grass. This breed will not fatten at young ages; instead of fattening the animals keep on growing. Thus, for the modern market the joints are too large for ordinary household purposes though the meat is bought readily for the catering trade.

South Devons, as dairy animals, have not really spread from the south-west of England, but the business in store cattle has been considerable.

Welsh Black—Welsh Black cattle have been kept in Wales for centuries but were not recognised until the latter part of the nineteenth century. At first there were two breeds, namely, one from the north and the other from the south; recently those in the south have lost a little in popularity, though the breed has remained firmly established in the mountainous districts in North Wales. In 1905 the breed became united into one common Herd Book. This breed is the toughest of the dual purpose (or even the dairy) breeds for they

not only live but milk relatively well in very cold, exposed areas where food supplies are of very poor quality. The breed is usually entirely black though sometimes small areas of white appear upon the underside of the belly. The frames are usually large and bony and do not show very marked dairy wedges. The udders are inclined to be pendulous and perhaps a little small for the size of the cows. As might be expected from such hardiness, the skins are a trifle heavy and covered with a thick coat of

TABLE 36: BIRTH WEIGHTS—LIVE WEIGHT AGES OF FIRST CALVINGS

Breed	Mature av. live weight of cows	Birth weight of calves	Ages at which heifers calve first time
	lb.	lb.	months
Ayrshire ...	1,000	70	27–30
British Friesian	1,250	95	30–33
Guernsey ...	950	65	24–30
Jersey	800	55	21–24
Kerry	850	60	30
Dairy Shorthorn	1,250	85	27–30
Dexter	650	50	30
Lincoln Red Shorthorn ...	1,300	95	30
Red Poll ...	1,100	75	27–30
South Devon ...	1,450	110	30–36
Welsh Black ...	1,150	80	30–33
Aberdeen Angus	1,100*	70*	24
Devon	1,150	80	24
Galloway ...	1,050*	70*	36
Hereford ...	1,300*	85*	24
Highland ...	1,200*	75*	36
Sussex	1,150*	80*	24
Shorthorn ...	1,250*	85*	24

* Estimated.

TABLE 37 : COMPARATIVE YIELDS OF DIFFERENT BREEDS OF COWS

Breed or breed type	Number of herds	Average yield (lb. of milk) cows	Average percentage butter-fat	Average yield (lb. of butter-fat)
Main Breeds				
Ayrshire	4,148	8,738	3·84	336
Dairy Shorthorn ...	3,285	8,095	3·56	288
Friesian	8,915	10,015	3·53	354
Guernsey	2,171	7,649	4·55	348
Jersey	1,924	7,426	5·01	372
Red Poll	582	7,782	3·63	282
Other Breeds				
British-Canadian Holstein-Friesian	24	10,854	3·48	378
British White ...	8	7,438	3·97	295
Devon	7	5,913	4·04	239
Dexter	19	5,171	4·20	217
Kerry	9	7,651	3·98	305
Lincoln Red Shorthorn	41	7,595	3·63	276
Northern Dairy Shorthorn ...	177	7,774	3·54	275
South Devon ...	335	6,515	4·19	273
Welsh Black ...	92	6,361	4·05	258
Mixed and others ...	2,235	8,322	3·50	291
Total All Breeds ...	23,972	8,902	3·84	342

Milk Marketing Board, National Milk Records—Annual Reports for the year ending September, 1956.

TABLE 38 : DEAD WEIGHT (lb.) FOR VARIOUS KILLING PERCENTAGES

Live weight (cwt.)	Dead weight (lb.) giving killing percentage		
	54 per cent.	56 per cent.	58 per cent.
8	484	502	520
8½	514	532	552
9	544	564	585
9½	574	595	617
10	605	627	650
10½	653	658	682
11	665	690	715
11½	695	721	747
12	726	753	780
12½	756	784	812
13	786	816	845
13½	816	847	877
14	847	878	910

TABLE 39 : PRICE IN PENCE PER POUND FOR VARIOUS PRICES PER CWT.

Price in shillings per cwt.	Equivalent price in pence per lb. for killings		
	54 per cent.	56 per cent.	58 per cent.
130	25¾	24¾	24
140	27¾	26¾	25¾
150	29¾	28¾	27¾
160	31¾	30½	29½
170	33¾	32½	31½
180	35¾	34½	33¼
190	37¾	36¼	35
200	39¾	38¼	37

black hair. Milk yields are not high, as might be expected. The butter-fat is the second highest of the dual purpose breeds. The steers are reared locally and sold, when about two years old, to the Midlands for fattening on grass, for which purpose they are very popular. Quite frequently the breed is crossed with the Hereford to produce rather quicker growing calves ready for sale fat some six or twelve months sooner than the steers of the pure breed. Welsh steers are very popular with butchers to meet modern demands, since they produce smaller joints than those obtained from some of the more widely kept breeds.

BEEF ANIMAL BUTCHERS' CUTS

1. Leg.
2. Round.
3. Aitchbone.
4. Rump.
5. Thick Flank.
6. Sirloin.
7. 6-rib Piece.
8. 3-rib Piece.
9. 3-rib and Leg of Mutton Piece (or Chuck).
10. Plate.
11. Brisket.
12. Clod and Sticking Piece.
13. Fore Shin.
14. Thin Flank.

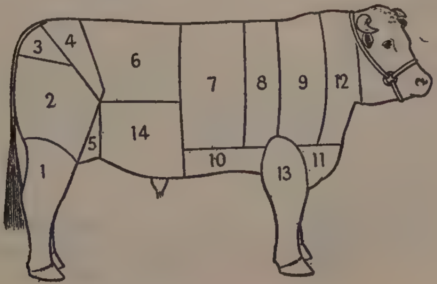


Fig. 21

Measuring of Cattle for Weight—Each cubic foot of living carcase is equal to 3 stones Imperial of butchers' carcase. Therefore 576 cubic inches = 1 stone.

The solid contents of the body (length × diameter^2 × 0·7854) in cubic inches if divided by 576 gives the dead weight in Imperial stones.

Rule 1. Girth^2 × 5 lengths ÷ 21 = weight in Imperial stones. Measure in feet.
Rule 2. Girth^2 × length ÷ 0·7344. Measure in inches.
Rule 3. Girth^2 × length × 0·07958 ÷ 576. Measure in inches.
Rule 4. Girth^2 × length × 0·00013816. Measure in inches.
Rule 5. Girth × length × 23 ÷ 14. Measure in feet.
Rule 6. Girth^2 × length × a given decimal.

In the calculation strike off to the left as many points as are in the decimal. Result is Imperial stones. Measure in feet.

Condition of beast.	Decimal to use.
Moderately fat	0·23
Fat	0·24–0·25
Prime fat	0·26
Very fat	0·27

The length of an animal is taken straight along the back from the square of the shoulder to the square of the buttock. The girth immediately behind the shoulder.

The hide alone in the case of 2-year-old steers shown at Smithfield averaged one year about 6·25 per cent. of the live weight and in the case of the 3-year-olds 6·6 per cent.

Regulations of the Smithfield Club regarding Dentition—Cattle having their central permanent incisors cut will be considered as exceeding one year and six months.

Cattle having their central permanent incisors fully up will be considered as exceeding one year and nine months.

Cattle having their second pair of permanent incisors fully up will be considered as exceeding two years and three months.

Cattle having their third pair of permanent incisors cut will be considered as exceeding two years and eight months.

Cattle having their fourth pair of permanent incisors fully

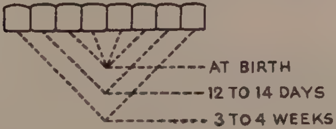
FIG. 22: DENTAL FORMULA FOR A FULL MOUTH

P.M.	T.M.	INC.	T.M.	P.M.	
$^3/_3$	$^3/_3$	$^0/_4 \mid ^0/_4$	$^3/_3$	$^3/_3$	$= 32$

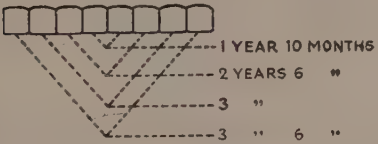
The corner incisors are sometimes looked upon as canine teeth, but are shed like the others.

TEETH AS INDICATIVE OF AGE

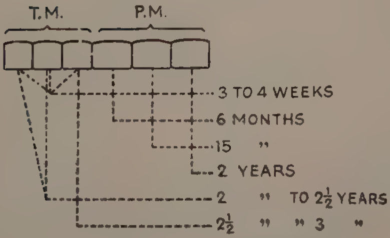
Appearance of Temporary Incisors



Appearance of Permanent Incisors



Appearance of Molars



The ox has no incisors in the upper jaw.

up and their anterior molar showing signs of wear will be considered as exceeding three years.

NAMES OF CATTLE

MALE

At birth: Bull calf; bullock calf if castrated.

First year: Year-old bull; stott (castrated). Yearling.

Second year: Two-year-old bull; stott, steer, ox, or bullock.

Third year: Three-year-old bull; stott, steer, ox, or bullock.

FEMALE

At birth: Quey calf, heifer calf, or cow calf.

First year: Year-old heifer or quey. Yearling heifer.

Second year: Two-year-old heifer or quey.

Third year: Three-year-old heifer or quey; becomes a cow on bearing a calf.

" Stott " is sometimes applied to a bull of any age, and sometimes to an ox or steer after the fourth year. " Segg " is applied to a bull castrated after service.

" Stirk " is limited to males and females under two years in Scotland, while it is usually applied to females only in England, the males being " steers."

" Heifer " is almost universally applied in England to a young cow in calf, but in some places, especially in Scotland, it is limited to speyed animals.

A cow after being served with bull should be an " in-calver." If she proves barren, is " eild " or " farrow "; when she stops yielding milk, is " yeld " or " dry." When a bull and quey calf are dropped at one birth, the latter is generally a " free-martin "—that is, barren.

Breeding—Cows are mated for the first time at ages which vary with breed, farm policy and the state of development and growth of the animal. Table 40 shows typical ages for certain breeds.

At the present time certain farmers calve down their dairy cows at younger ages than was once thought desirable. For example, Friesians, Ayrshires and Shorthorns at two years old. To calve animals down successfully at this young age demands good rearing from birth.

TABLE 40: MATING AGES

	months
Jersey	12–15
Guernsey	16–18
Ayrshire...	18–21
Shorthorn	21–24
Lincoln Red Shorthorn	21–24
British Friesian	21–24
Welsh Black	21–24
South Devon	24–27

TABLE 41 : OESTRUM (HEAT) PERIODS

Duration of oestrum	Return after parturition	Return if no conception
A few hours up to one day	21–28 days	Approximately 21 days

Period of gestation is—281–285 days.
40–41 weeks.
9½ months.

Signs of Pregnancy and Approaching Parturition—Given in general order of occurrence:—

1. Heat periods cease.
2. Milk yield shows slight fall about 140 to 150 days after conception.
3. At about sixth month calf may be felt through the right flank.
4. Udder increases in size and later may become hard and painful a few days before calving.
5. Ligaments around the tail loosen a few hours before calving.
6. Animal walks unsteadily.
7. Animal becomes uneasy and appetite may become poor.
8. Bladder appears and bursts.

The calf should then be born within a short period.

Signs of Normal Health in Cattle—Appetite keen; animal chews cud contentedly; dung semi-solid; urine a

clear colour; passage of dung and urine several times a day; coat shiny, animal bright and alert; eyes bright and not sunken; breathing easy; lick marks on coat; animal quiet and content; milk yield showing only slight day to day variations; horns normal to touch, that is neither hot nor cold. Temperature: 101·8° to 102·4° F.; Pulse: 45–50 per minute; Respiration: 12–16 per minute.

HORSES

HEAVY BREEDS

DEVELOPMENT of mechanical power on the farm has latterly proceeded so rapidly and has been so varied in its purpose as to constitute a serious threat to the heavy horse. As a result of increased cultivation and the greater prosperity of the farming industry during the war years and since, the horse has been replaced by the tractor to an extent which is causing the authorities some dismay. For while the extended use of motor power is inevitable in a progressive industry, the importation of every gallon of motor fuel needed might in emergency impose undue strain on the transport protecting service.

On the small or medium farm the heavy horse should still find a place on account of its handiness, adaptability, and reliability in most circumstances. Even on the larger holdings the farmer is liable to be confronted with tasks uneconomical for the tractor yet well within the capacity of a sound horse. To use a 20 h.p. tractor for a one-horse job is wasteful of power and very costly.

Shires—In England and Wales the Shire still holds a numerical superiority over the three other heavy breeds—Clydesdale, Suffolk and Percheron. For centuries it has been the main source of farm field power. Some have traced its origin to the war horse used in the French campaigns of the Tudor kings. Bred mainly in the Midland counties, its type exists throughout the country, and the colour ranges from the blacks and greys which were popular in the early days of organised Shire breeding to dark browns, browns and bays. The blacks and greys, indeed, have a way of cropping up and creating a fashion from time to time, but in between such periods, the dark browns predominate.

In maturity the stallion weighs from 17 cwt. to a ton and stands 17 hands high. Clean, flat bone on massive legs is looked for, and the action must be straight and free. Present tendency is to limit the amount of hair on the legs to give the animal a clean limb free from the threat of grease. In spite of the weight and power the Shire is an easy mover and the

characteristic willingness and courage, combined with a general clean bill of health, have brought widespread popularity as a source of adaptable animal power.

Clydesdale—Although originally found and developed chiefly in the Valley of the Clyde the great Scottish horse is capable of meeting varied conditions in many countries outside its own. Special attention has been devoted to the maintenance of a type with legs and feet that wear well and stand the shock imposed by the granite setts of cities as well as the strain of heavy clay land. Greater importance is now attached to the wearing qualities of the limbs than to mere weight.

Clydesdale stallions average about 16·3 hands, the mares 16·1 hands; the popular colour is dark brown, sometimes even darker and approaching black, with a little white on the face and with one or more white feet. Strength of constitution and freedom from vice are conspicuous virtues and their fast walking pace gives Clydesdales an air of activity and fitness which makes them popular on the small mixed farm.

From Scotland the breed has spread throughout the northern counties of England and is probably the best known of all British heavy breeds in overseas countries, especially in the countries of the British Commonwealth. Exports were resumed on a fair scale immediately after the 1939–45 war.

Suffolk—The great horse of the Eastern counties is famous for its clean legs, quick movement and power. The nickname—the "Punch"—may be an indication of the girth behind the shoulder or may have had something to do with the more thickset type prevalent in the past. Yet the Suffolk has probably been subjected to varying fashionable points less than other breeds, having always been bred for its strength of limb, excellence of feet, and shapeliness of hoof.

Colour, too, has altered but little. From earliest times clean-legged horses of the Eastern counties have been brown, some say ever since the Norman invaders brought horses over with them. To-day a bright shade of chestnut is in favour, with the mane and tail sometimes of a light or blonde shade. For the thick withers, the deep barrels, and the well-rounded quarters the legs look rather light but their freedom from hair gave the Suffolk an advantage when, after World War One, the demand was for hairless legs, especially in horses intended

to work on heavy soils. The Suffolk has a reputation for soundness.

Percheron—Few people in Great Britain were aware, before the 1914–18 war, of the existence of the Percheron breed of horses. It was one of the heavy breeds of France, and proved so efficient in that conflict that British horse breeders serving on the Continent organised the importation of a substantial contingent to form the foundation of a definite type to serve on the farms and in the towns of this country.

British-bred animals have increased greatly in numbers and are popular for their handiness, their good health, and their trouble-free limbs.

The general colour is grey, with an occasional black. Stallions weigh from 16 cwt. to a ton, with a height of between 16 and 17 hands; the mares, averaging about 16·2 hands, weigh from 14 to 16 cwt. Even at big weights the Percheron is a quick mover and can shift heavy loads smartly and willingly. The breed requires the minimum of attention and can carry on with moderate rations.

No matter what breed of mare is put to the pure-bred stallion, the clean limbs are transmitted to the progeny. Resistance to disease, longevity and regular breeding have strengthened the hold of the Percheron on the work of British farms and among commercial users of horses.

LIGHT BREEDS

Hackneys—Hackneys are less seen to-day, but at one time they were very popular and certainly the showiest of our British breeds, with spectacular leg action in harness, great pace and high courage. In tandem or in pairs they commanded attention. The International Horse Show in the early days at Olympia, largely centred around the gaiety of the driven Hackney. Yet the ride-and-drive type of Hackney is still being bred by a few enthusiasts who are determined not to allow a peculiarly British breed whose speed and endurance demonstrate the frequent infusions of Thoroughbred blood to die out.

At one time the Hackney, next to the Thoroughbred, was the horse most in demand for export. Prize-winners of elegance possessing high leg action went especially to the United States and to South America. General height is

15 hands; sound feet and clean legs with a touch of white are essential.

Thoroughbred—Britain's best known horse, used the world over not only for racing but for crossing to add speed and perhaps elegance to other horses and ponies, is the Thoroughbred. The breed was founded by Charles II who introduced the best Barb, Arab, or Turk mares procurable. From these three, great lines were derived leading to the stallions Herod, Eclipse and Matchem, from which are descended the greatest of modern race-horses. Speed is the dominant requisite and must not only be possessed by a Thoroughbred but also indicated by the general appearance.

Hunters—A horse for hacking as well as for following hounds naturally requires speed and courage. The Hunter has been bred with these qualities most in view although with a considerable variation in conformation in consequence. The Thoroughbred stallion is very largely used and although a fair proportion of pure-bred animals exist most Hunters are the progeny of mares of proved prowess in the hunting field sired by a Thoroughbred stallion. Light cart mares and pony mares are sometimes successfully mated with the Thoroughbred. But substance, quality, speed and endurance—all essential factors—are not easy to combine and often the progeny of breeding from pony mares lack the size so much sought after. Good hunting ancestry on the dam's side is therefore desirable.

PONIES

Ponies vary in height from as little as 8½ hands to about 14 hands and the native breeds are Dales, Dartmoor, Exmoor, Fell, Highland, New Forest, Shetland, Welsh.

Exmoor—These ponies and those of Dartmoor have several points of resemblance. Both are used for the breeding of Hunters and Polo ponies.

Fell—This is one of the largest of British ponies, standing up to 14 hands. It is thickset and powerful, and usually black or dark brown. In its native Northern counties and elsewhere it is often known as the Galloway, being noted for speed, great activity, and sound constitution.

Highland—This breed is very varied in type but can often be recognised by the stripe along the back. Standing up to 13 to 14 hands, these ponies are remarkable for great strength in relation to size. They are sure-footed, hardy, and able to live on rough pasture throughout the year.

New Forest—Running more or less wild in the New Forest of Hampshire, this breed of grey ponies possesses a measure of Thoroughbred blood to which their spirit and speed is due. They have strong constitution, stand from 12·2 to 13 hands, and the mares are often used for breeding up to the standard laid down for polo and riding ponies.

Polo—Native British ponies have formed the basis for the development of this distinct breed, aided by the introduction of Thoroughbred and Eastern blood. Breeders have a preference for mares with a good polo-playing record, especially those likely to produce progeny with substance and weight-carrying ability as well as quality and speed.

Shetland—At one time this breed was in great demand for pit work in the North of England but the modern Shetland, the smallest ($7\frac{1}{2}$ hands to 10 hands) of British breeds, is wanted mainly as a first riding pony for children and for light harness.

Welsh Mountain—This is perhaps the oldest breed of native pony, running semi-wild on the mountains of Wales. Noted as a sure-footed, handsome animal, natural and true in the gallop and an excellent jumper, it has been used as the foundation for many other successful types. It averages 12 hands in height and in colour varies greatly, with a preference for grey.

A type of small horse in favour to-day is the **Cob**. These are short legged and stand about 14 hands. They carry more bone than most ponies and are mostly crosses of heavy breeds of horses with a pony breed.

BREEDING—MANAGEMENT

Mares and stallions must be pure bred and of high individual merit. The Horse Breeding Act forbids the use of stallions suffering from cataract, roaring and whistling, ringbone, navicular disease, stringhalt, shivering and defective genital organs.

Fillies under two years of age should not be mated; colts in their third year may serve a small number of mares. In the fourth and fifth year colts may serve up to sixty mares a year and mature stallions eighty. Agricultural mares normally foal between April and June. The gestation period averages 11 months with a 10 to 14 day variation either way. Oestrous occurs four to seven days after foaling, lasts five to seven days, and successive heat periods are at intervals of 20 to 21 days.

Exercise for In-Foal Mares—Mares can do ordinary farm work for the first six months of pregnancy. After this do not work them in shafts nor give heavy or prolonged work. Light work in chains is safe up to a week or so before foaling. Lack of exercise in the few weeks before foaling is bad but providing the mare is at grass, lack of actual work will not result in harm. Nearer foaling it is important to feed a laxative diet, taking care not to overheat but feeding a ration for slightly harder work than the mare is in fact doing.

Foaling—Imminent foaling is shown by the muscles around the tailhead loosening, the udder swelling and the appearance of waxy drops on the end of the teats one or two days prior to parturition. If the mare is to foal in a box this must be large, light, clean and airy. The duration of labour is usually short and presentation difficulties rare. It is important to ensure the mare cleanses properly. After the navel cord is cut leave the mare and foal alone.

Rearing of the Foal and Management of the Mare—Give the mare laxative, good quality food after foaling, e.g., bran mashes and clover hay. In suitable weather mare and foal may go out to grass in the daytime two or three days after foaling. Gradually increase the time at grass until they are lying out at night which will usually be two or three weeks after foaling. If foaling has been early in the year and the weather is not good, house mare and foal at night but ensure the mare is given adequate daily exercise. Whilst mare and foal are lying out hand feeding is not necessary.

The mare should not work for at least a month after foaling, indeed until after weaning, but if she is given work prior to weaning this must be light, of short duration and not likely to cause sweating. Do not separate mare and foal for more than two or three hours at a time. If work prior

to weaning is necessary, feed for the work done and add 3 to 4 lb. of mixed corn daily.

During the first summer foals should be handled, accustomed to a halter and led about. Regular early lessons are invaluable.

Wean when four to six months old. Make the separation sudden and final and closely confine the foal for two or three days and then put back to pasture. Put the mare to work to dry her off.

On good pasture weaned foals do not require any other food, but if weaning is late in the year, the foal backward, or the grass poor, a good supplement is crushed oats and separated milk.

During a foal's first winter it is usual, except in mild areas, to house at night and turn out by day. Feed well, for example, oats 4 lb., bran 2 lb., chaffed hay 4 lb., in two feeds daily. In times of frost or snow spread some hay on the pasture.

Young horses do not need rich summer pasture and mixed stocking is better than letting the animal graze by itself.

During the second winter a little hay in addition to the grazing may be needed, but in January and February up to 6 lb. of grain per day may be required according to the condition of the animal and the climate.

Colts are castrated about one year old. This is a dangerous operation and should be performed by a veterinary surgeon.

BREAKING IN

Start with the foal but the actual breaking-in routine commences when the horses are $2\frac{1}{2}$ years old. First accustom the animal to harness and then lead it about. Next drive on long reins and teach it to answer to the bit. Finally put to work ploughing beside a steady horse with the youngster in the furrow, thus teaching it to walk straight. Work in shafts should not be attempted for some months and then a horse should not be worked more than an hour or two each day. By three years of age the horse is fit for regular work.

BREEDING AND MANAGEMENT

A horse has a small stomach. In periods of hard work feed regularly, at least three times per day, and allow one

hour per meal. Do not give large meals after heavy work. Water at least four times daily, usually before meals, not immediately afterwards, and loosen girths prior to watering. When a horse is very hot and tired offer small amounts of water at short intervals until thirst is quenched. If horses are stabled in summer give a last watering late at night.

Oats and hay are basic foods. Dusty, mouldy, badly made hay is not good, whilst maize, barley and beans are often fed. Horses doing light work or idle may have oat straw to replace part of the hay. The ration fed will depend on the condition and size of the animal as well as the nature of the work.

A typical ration for a 1,500 lb. horse on heavy work is good hay 14 lb., oats 20 lb., with some of the hay fed chaffed with the oats; 3 to 4 lb. of beans may replace $3\frac{1}{2}$–$4\frac{1}{2}$ lb. of oats. If work is regular but not heavy the following ration is adequate—Crushed oats 12 lb., bran 2 lb. and hay 14 lb.

During idle periods reduce the grain feed. A common practice is to feed a bran mash instead of grain on Saturday nights. This is a laxative and is a wise measure in view of the Sunday rest. Reduction in grain feed is the more necessary after some days' hard and continuous work.

During summer and when horses are not hard worked, 6 lb. of oats for every half-day's work is sufficient.

Clipping and Grooming, Shoeing—The more work a horse performs the more it sweats and the greater the need for grooming. Working horses should be groomed at least once a day and when they arrive back very hot a scraper and hay whisk is best used to take off the sweat. Do not wash horses' legs, but allow the mud to dry and brush it off.

Before the coat is fully grown at the start of the winter clip trace high. Head, neck, back and quarters are not clipped. The hair on the coat is left on down the flanks and body to a point level with the point of the shoulders and straight back. Legs are clipped down to half-way between elbows and knees on the fore legs and between stifle and hocks on the hind legs. Shoeing is usually required every six to eight weeks.

Bedding—Do not leave bedding down all day. Sweep floors once a day and hose them down once a week at least. Old bedding fit to use again should be placed on top of and across new straw for this gives a more elastic bed.

AGE

A good sound horse can work well on into its 'teens. Age is indicated by the teeth as follows:—

DENTAL FORMULA FOR A FULL MOUTH

P.M.	T.M.	C.	I.	C.	T.M.	P.M.
$^3/_3$	$^3/_3$	$^1/_1$	$^3/_3 \mid {}^3/_3$	$^1/_1$	$^3/_3$	$^3/_3 = 40$

NAMES OF HORSE

Horse

During 1st year—Colt foal.
During 2nd year—Yearling colt.
During 3rd and 4th year—Two- and three-year-old.
At 3 years of age Entires or Stallions: Geldings if castrated.

Mare

During 1st year—Filly foal.
During 2nd year—Yearling filly.
During 3rd and 4th year—Two- and three-year-old.
At 3 years of age Mares.

PIGS

THE principal breeds of pigs are:—

Large White or Yorkshire—Numerically the most popular breed in Britain. Colour should be all white. Ears long, thin, slightly inclined forward and fringed with hair. Head moderately long, face slightly dished, snout broad, not too much turned up, jowl light, wide between the ears. Most widely distributed breed in the world. Used pure for production of Wiltshire baconers and crossed with other long breeds to produce commercial baconers.

British Landrace—Introduced as the Swedish *Lantras* from Sweden in 1949 and 1953. It is an all white pig with semi-lop ears, a particularly long body and large well rounded hams. Developed originally for producing Wiltshire baconers but used also for crossing with other breeds for bacon production.

Large Black—Black in colour with long, thin, lop-ears well inclined over the face. Breed Society first established in 1899. A popular breed for grazing and as a consumer of poorer quality foods. Constitution and skin suited particularly to thrive in both hot and cold climates. Produces good baconers when crossed with the Large White.

Wessex Saddleback—A long sturdily built breed with lop-ears not quite so pendulous as the Large Black. The ideal colour marking is black except for a continuous belt of white over the shoulders and fore-legs. This pattern not yet genetically fixed and some all-blacks occur. Records of numbers born and reared exceptionally good. Sows are good mothers and the breed does well under very rough conditions.

Essex Saddleback—Colour markings are similar to Wessex Saddleback but the white saddle is usually wider and clearer, and there should in addition be white on both hind feet and the tip of the tail. Whole black colour occurs as in the case of Wessex Saddleback. Skin and bone somewhat finer than Wessex Saddleback. Produces good baconers either pure or crossed.

Berkshire—One of the oldest British breeds. Originally black, red and white in colour. The typical colour pattern

now consists of an all-black body with white on all four feet, tip of tail and snout. Mature animals are smaller than the bacon breeds but breed is much earlier maturing. Carcases carry high proportion of lean to bone, but if fed to heavy weights, or over-fed with meal, carcases may carry too much fat in spite of proportion of lean. A good grazing pig and popular where pork is required and where climate is hot. First cross with Large White usually all white in colour.

Tamworth—A breed of medium size, long, lean and golden red in colour. Longer in the snout than any other British breed. Carcases less liable to be over-fat than other breeds though not so rapid growing as others. Good for crossing with other bacon type or pork type breeds.

Middle White—An early maturing type of the original Yorkshire White pig. Developed from the Large White and the now extinct Small White breed. Shows more influence of the white Chinese blood than any other British breed. Most early maturing type and suitable for small pork production but can produce baconers when crossed with Large White.

Gloucestershire Old Spots—A medium sized, general purpose type with a few large black spots on a white ground. A sturdily made pig which may grow strong on good land though on limestone the breed may show greater fineness. Capable of running out all the year round on heavy land without fear of hoof damage or rheumatism and well suited to woodland foraging.

Welsh—An all-white long lop-eared pig with good hams. Has been called the British Landrace because of its similarity to the Danish breed. The lop-ears facilitate good grazing habits and the colour and conformation meet the requirements for bacon. Pedigrees have been registered since 1918.

National Long White Lop-Eared—Breed Society founded in 1921, though breed popular in the Tavistock district of Devonshire and neighbouring parts of Cornwall for many years. Though rather more a dual purpose pig, somewhat similar to Welsh breed and amalgamated with that Society from 1926 to 1928.

Other Breeds—Other breeds of less importance numerically include the Ulster Large White, Lincolnshire Curly Coat and the Cumberland pig.

WEIGHTS

When referring to the weights of pigs, it is important to make it clear whether it is the live weight or the dead weight that is concerned. There is, of course, no difference between the total weight of an animal alive or dead, but the expression "dead weight" is used to mean the weight of the carcase after it has been eviscerated. In the contracts of the Pigs Marketing Board dead weight was defined as being "the weight (after the animal heat has departed) of a dressed carcase including the skin, the head with the tongue, the kidneys, the tender loins, the fleck or flare, the tail, the backbone and the feet." Where a pig was weighed before the animal heat had departed, the scale of deduction for shrinkage from hot to cold dead weight was:—

Dead weight (hot)	Shrinkage lb.
Up to 9 sc. 9 lb.	4
9 sc. 9 lb. to 10 sc. 15 lb.	5
Over 10 sc. 15 lb.	6

Offals are normally divided into primary offals and secondary offals. The first, not included with the carcase, are the blood, pluck (including lungs, heart, liver, oesophagus and trachea), abdominal contents (including stomach, intestines, spleen), bladder and mesenteric fat. In cattle and sheep the primary offals include head, feet, tail and skin which in the case of these animals are often referred to as the fifth quarter. Secondary offals are those parts of the carcase which are removed when the two sides are being prepared for manufacturing into bacon. These include head, feet, tail, fillet, kidneys, flare fat, bones and trimmings. When the weight of a pig is being referred to, this is sometimes stated as the live weight, but occasionally it is given as the estimated dead weight, and it is important that the method of description should be made clear. Live weights are commonly given in scores of 20 lb. or stones of 14 lb., though they are preferably expressed in pounds. All prices are now commonly given in scores. There was originally a Smithfield stone of 8 lb. but its use is now illegal. (For every 14 lb. live weight of an average bullock one could expect to get 8 lb. carcase weight.)

CARCASE JUDGING

The scale of points adopted for both pork and bacon under the Smithfield method (Davidson, Hammond, Swain and Wright) was as follows:—

TABLE 42

	Marks	
	Porkers	Baconers
1. Marketing points:—		
Colour—clean, fresh, white ...	5	5
Skin—smooth and fine ...	5	
Dressing — freedom from bruises and hair	5	5
	15	10
2. Breeders' points:—		
(*a*) By Inspection:		
Hams—well filled and fine boned	8	8
Shoulders—light	7	7
Streak—thick, full of lean meat	12	12
(*b*) By Measurement:		
"Eye muscle" of Loin—thick	28	28
Back Fat thickness—correct proportion	20	20
Body Length—in proportion to weight	20	20
Leg Length—short ...	5	5
	100	100
3. Suitability of Carcase Weight ...	—	15
Total Marks ...	115	125

RATIONS

TABLE 43: RATIONING TABLE

		Meal consumption per head per day (as lb. of dry meal equivalent)	Nutritive Ratio
BREEDING PIGS—			
In-pig sows ...	...	2–6	1 : 4½–5½
Suckling sows ...	...	8–12	1 : 4½–5½
Stock boars ...	...	3–7	1 : 4½–5½
FEEDING PIGS—			
Age in weeks	Approx. Live Weight lb.		
3–8	30	1½	
8	30	1½	
9	32	1¾	
10	38	2	1 : 4–5
11	43	2¼	
12	50	2½	
13	57	2¾	
14	64	3	1 : 5–6
15	73	3¼	
16	81	3½	
17	90	3¾	
18	98	4	1 : 6–7
19	106	4¼	
20	116	4½	
21	124	4¾	
22	134	5	
23	143	5¼	
24	154	5½	
25	163	5¾	1 : 7–8
26	172	6	
27	181	6	
28	190	6	
29	199	6	
30	208	6	

TABLE 44: APPROXIMATE CARCASE DRESSING PERCENTAGES

(All figures are approximate estimates based on average figures obtained in practice from pigs of bacon type fed largely on concentrates. Live weights taken before morning feed, i.e., after about 14 hours' fast. Dead weights taken cold when carcase room temperature.) (H. R. Davidson.)

Live Weight lb.	Carcase Weight lb.	Carcase Dressing Percentage
81	50	61·7
90	58	64·4
98	65	66·3
106	72	67·9
116	80	69·0
124	87	70·0
134	95	71·0
143	102	71·4
154	111	72·0
164	119	72·7
173	126	72·9
184	135	73·4
195	144	73·8
207	154	74·4
220	165	75·0
231	176	76·2
241	185	76·8
251	195	77·6
263	206	78·3
272	215	79·0
282	226	80·0
291	237	81·5

CARCASE ANALYSIS

The following analysis can be taken as a guide to the approximate weights likely to be obtained from an average quality pig of 200 lb. live weight. The percentages will vary materially for pigs of lighter or heavier weights.

The weight of trimmings may vary considerably according to the method of cutting adopted, and if sides are boned for rolling this will have an obvious effect.

TABLE 45: ANALYSIS OF BACON CARCASE

Total Weight — Primary Offals	lb.	oz.	lb.	oz.	Approx. Percentage of Live Weight
Blood	7	0			
Thymus (sweetbread)		5			
Diaphragm		14			
Lungs and trachea ...	1	7			
Heart		9			
Liver	4	12			
Spleen		3½			
Pancreas		4			
Kidneys		13			
Flare fat	3	6			
Caul fat (omentum) ...		5			
Gut fat (mesentery) ...	2	5	22	3½	11·1
Oesophagus		2			
Stomach empty ...	1	1			
Intestines empty ...	5	8			
			6	11	3·4
Hooves and hair ...	1	4			
Gall bag, bladder, etc.		6			
			1	10	0·8
Loss, intestinal content, evaporation, etc. ...	19	7½			
			19	7½	9·7
Cold carcase, ex kidneys and flare ...	150	0	150	0	75·0
Totals ...			200	0	100·0
Secondary Offals					
Head, ex tongue ...	13	12			
Tongue		12			
Fillets	1	8			
Trimmings, fat and tail	5	4			
Bones and trotters ...	8	12			
			30	0	15·0
Two dressed sides, prepared for cutting and curing ...			120	0	60·0

TABLE 46: PROPORTION AND VALUES OF CUTS IN A GOOD QUALITY WILTSHIRE SIDE

(H. R. Davidson)

Cut	Weight lb.	Per cent. of total weight
Gammon hock	8·7	15·6
Corner gammon	4·4	7·9
Long loin	3·2	5·7
Short back	4·3	7·7
Rib back	8·8	15·8
Flank	2·6	4·6
Thin streaky	2·8	5·0
Thick streaky	5·2	9·3
Collar	7·3	13·0
Fore hock	8·6	15·4
Gammon	13·1	23·5
Middle	26·9	48·1
Fore end	15·9	28·4

TABLE 47 : ANALYSIS OF SMALL PORKER CARCASE

(H. R. Davidson)

Cut (both sides)	Weight lb.	Per cent of total weight
	lb. oz.	
Leg	18 0	24·6
Loin	13 12	18·8
Neck (spare-rib)	16 0	21·8
Belly or streak	10 12	14·7
Spring (including hand) ...	7 12	10·6
Head...	7 0	9·5
Total ...	73 4	100·0

Live weight ... ... 109 lb.
Carcase weight ... 73 lb.
Dressing percentage ... 66·9 per cent.

NAMES OF PIGS

Originally the English name for a pig was a " swine " and the word " pig " was used for the young animal before weaning—hence the expression " sow and pigs." The word piglet is therefore synonymous with " calflet," " lamblet " or " foallet." As the result of a competition in " Farmer & Stock-Breeder " (Aug., 1956) the following definitions were suggested:—

Swine	A term inclusive of all the undermentioned.
Pigs	Male and female swine of less than a certain age (say 8 weeks).
Gilts and Sows Boars Hogs, and others	As at present understood, but above the age of pigs.

Castrated male pigs are referred to as hogs or barrows. Maiden female pigs are called gilts, yelts, yilts or hilts. Female breeding pigs are usually referred to as gilts until their first litter has been weaned, after which they are called sows. Uncastrated males are known as boars, and female pigs which have had the ovaries removed are referred to as having been spayed. A male pig castrated after having served is referred to as a stag or a brawner. Small thriftless sucking pigs are known variously as dolly, Anthony, sharger or runt pigs.

BREEDING MANAGEMENT

Gilts should be served for the first time when they are eight to ten months old. Boars may be used for service at the same age but should be sparingly used until they are 11 to 12 months old. Sows come in season approximately every 21 days and remain on heat for from one to three days. Sows will normally farrow about 115 days after service. Boar pigs should be castrated at six weeks of age and the whole litter weaned at eight weeks of age. When this is done it should be possible for the sow to have two litters within 12 months. The best months in Western Europe for farrowing are March and September. Breeding sows should receive as much exercise as possible, but should be placed in

their farrowing pen one week before due to farrow. Warmth in the farrowing pen is essential.

Feeding—Sucking pigs will start to eat solid feed at three weeks old and should be given a highly digestible ration behind a creep. From then until the pigs are about 12 weeks old the food should contain little fibre but plenty of protein and minerals. Barley meal, flaked maize, middlings, with milk by-products, meat and bone meal or fish meal are the best ingredients for young pigs. In later stages of fattening protein and minerals may be reduced. Bacon pigs should increase from one to two pounds live weight per day according to age.

Early Weaning—The weaning of litters at an earlier age than the usual 8 weeks has been made possible by the formulation of sow milk substitutes. Although these were at first given to very young pigs in liquid form it has been found that piglets of even 4–5 days old will eat them dry provided they always have plenty of clean fresh water to drink.

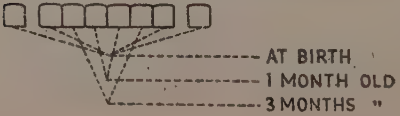
In practice many find that the losses from scouring when pigs are weaned before 10 days old makes it easier to wean between 10 and 14 days than a few days after birth, though the latter practice enables the greatest use to be made of milk substitutes and so to rear the greatest number of pigs per sow per year.

FIG. 23: DENTAL FORMULA OF A FULL MOUTH

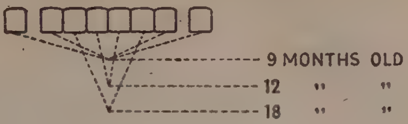
P.M.	T.M.	C.	I.	C.	T.M.	P.M.
$^3/_3$	$^3/_3$—$^1/_1$	$^1/_1$	$^3/_3$ | $^3/_3$	$^1/_1$	$^1/_1$—$^3/_3$	$^3/_3$=44

TEETH AS INDICATIVE OF AGE

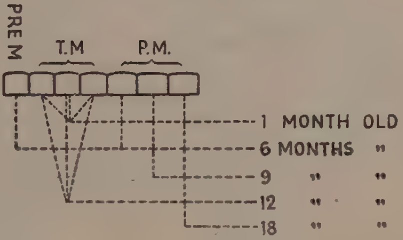
Appearance of the Temporary Incisors and Tusks



Appearance of Permanent Incisors and Tusks



Appearance of the Molars



REGULATIONS OF THE SMITHFIELD CLUB REGARDING DENTITION

Pigs having their corner permanent incisors cut will be considered as exceeding six months.

Pigs having their permanent tusks more than half up will be considered as exceeding nine months.

Pigs having their central permanent incisors up and any of the first three permanent molars cut will be considered as exceeding 12 months.

Pigs having their lateral temporary incisors shed and the permanents appearing, will be considered as exceeding 15 months.

Pigs having their lateral permanent incisors fully up will be considered as exceeding 18 months.

SHEEP

IN bygone days cheese made from the milk of ewes was an important product of Britain's sheep. Now our sheep are kept primarily to produce flesh, sold as mutton and lamb, with wool as an important secondary product.

There are between 30 and 40 recognised breeds of sheep in England, Wales, and Scotland. They are classified according to their habitat and type of wool; on land of high elevation Mountain, Moorland, and Hill breeds, and on land of lower elevation Longwoolled and Shortwoolled breeds. Systematic crossbreeding is more widely practised in sheep than with any other class of farm live-stock, hence our total sheep population contains a great number of crossbreds and mongrels, and some crossbred types are of very great commercial importance.

HILL BREEDS

To-day the hill breeds constitute the greater part of Britain's sheep population and from these the lowland sheep of Britain are being increasingly derived. The northernmost counties of Scotland—Caithness and Sutherland—contain the North Country Cheviot established as a separate breed with its own Flock Book as recently as 1946. **Cheviots** came first to these Scottish counties at the end of the eighteenth century and have remained there ever since. Introduced from the Border districts of south Scotland and north England they have diverged during the course of over a century and a half first into a separate type, and finally into a separate breed. The **North Country Cheviot** is a bigger, heavier, and altogether more massive and less graceful sheep than its modern Border cousin. Within recent years the North Country Cheviot has invaded its country of origin, and many North Country Cheviot flocks are now to be found in the Cheviot hills.

Between Sutherland and the Cheviots, the **Scottish Blackface** is the characteristic hill breed. Horned in both sexes, with a rough and hairy fleece, this breed is one of the hardiest in Britain. It is particularly well suited to

heather grazings. Not only in Scotland, but in limited areas of north England, Wales and Northern Ireland, even down to Dartmoor in Devon, wherever heather is extensive, the Scottish Blackface is likely to be found. In northern England, however, it has within the last few years lost a great deal of ground to its near cousin, the Swaledale.

The Scottish Blackface, largely because of the enormously wide diversity of habitat embraced within its territory, is also rather diverse in character, particularly in fleece character.

Many flocks of Scottish Blackface are found on the Border hills, but the typical breed of that country is the Cheviot. The Cheviot of the Western Border differs somewhat from that of the Eastern, and it is in the latter region that the North Country Cheviot invasion has been mainly felt.

In north England, from east to west, there is an interesting variety of breeds. Both Scottish Blackface and Border Cheviot are found, but the most popular breed is the **Swaledale,** which has spread greatly within the last 30 years. Closely related to the Scottish Blackface, it is leggier, more rangy, and carries a lighter fleece. It has a characteristically "mealy" nose and an interesting fleece, showing signs of the fine woolly undervest and coarser and more hairy outer jacket of most wild sheep breeds. Westwards across north England there is the **Rough Fell**, even more closely akin to the Scottish Blackface than the Swaledale, and finally the little white-faced, horned, and rough-coated **Herdwick,** regarded by many as the hardiest of the mountain breeds.

On the mountain spine running down to the Peak through the centre of England there existed many local breeds, some of them now reputed extinct. Among these is the **Lonk,** the Derbyshire Gritstone, the Limestone and the Penistone, of which only the two first survive in any numbers.

In Wales the **Welsh Mountain** remains supreme. This is Britain's smallest sheep and also one of the most active. The ewes are very good milkers. The breed is white or tan-faced, hornless in ewes, strongly horned in rams. It bears a fine and close fleece, inclining to kempiness, kemp being white, thick, dead fibres found among the true wool, particularly on the britch. The Welsh Mountain, both as regards numbers and the range covered, is one of the most important breeds in Britain.

On the isolated moorland country of south-west England, in Devon and Cornwall, there are local breeds in addition to the invading Scottish Blackfaces and Cheviots. Of these local breeds, the **Exmoor Horn** and the **Dartmoor** are best known.

All hill breeds provide appreciable amounts of wool and mutton. Within modern times, however, their main use has been to provide store sheep stock for the adjacent lowlands; wether lambs for fattening, and ewe stock—ewe lambs, young ewes, or more commonly cast-for-age ewes—for further breeding. The term cast-for-age means that once a ewe is five or six years old, depending on district, she is too old for a hard life, although she may have two or more useful breeding seasons on lowland farms. Wether hill lambs are fattened for slaughter.

LONGWOOLS

The Longwool breeds were once the most valued in England, being noted for their great weight of long, coarse-fibred wool. In medieval times, this English longwool was unique in character and indispensable for many kinds of woollen manufacture, bringing great wealth to the country. Until the latter half of the eighteenth century all Longwool breeds were kept to serve two purposes—to clip the heaviest possible fleece, and to consolidate and manure the arable land on which they were folded. For both purposes a massive, weighty sheep was needed and some of these old Longwools grew to immense sizes. Flesh production was mostly disregarded, until Robert Bakewell, of Dishley Grange, near Loughborough, began to improve the mutton qualities of the Longwool breed of his native Leicester. Bakewell had two purposes in view—to fatten more easily and at an earlier age. In both aims he succeeded, largely by inbreeding and progeny testing, methods novel to his age. Bakewell's New or Improved Leicester was used for crossing, at one time or another and to a varying extent, with all the other Longwool breeds of England. Several of these, named after their counties or districts of origin, achieved world distribution and fame. Nevertheless, within their native country and within recent years they have suffered a considerable decline both in numbers and importance.

The most famous of these English Longwool breeds are the Lincoln, the Kent or Romney Marsh, the Leicester, the Devon Longwool, the Border Leicester, the Wensleydale, and the South Devon Longwool.

The **Lincoln** is a breed of particular historical interest. This is one of the heaviest sheep breeds in the world and it carries the heaviest fleece. In former times it was even more weighty. The world importance of the Lincoln was based upon crossing with the Merino. When meat refrigeration, introduced about 1880, led to an international commerce in frozen mutton, the Lincoln was one of the English breeds most widely used to cross with the Merino ewe in order to improve the mutton qualities of the lambs. Moreover, the long wool of the Lincoln and the fine wool of the Merino blended well, retaining many of the valuable textile qualities of both. Two of the most important dual-purpose sheep breeds of the Southern Hemisphere—the Corriedale and the Polwarth—were founded on the Lincoln × Merino cross.

The **Kent** or **Romney Marsh** is regarded as the most typical breed in many districts of New Zealand, particularly in the North Island. New Zealand breeders have greatly modified it, however, paying particular attention to fleece improvement, with the result that the New Zealand Romney is best regarded now as a separate and distinct breed. In England the Romney is still an important breed in the Romney Marsh area. Probably no other breed is better suited to a very intensive system of grazing.

The **Leicester**, the first English Longwool breed to be improved for its mutton qualities, and used subsequently to impart such qualities to other Longwool breeds, has not had the same influence on the world's sheep as have the Lincoln and Romney Marsh. Reduced in numbers, it is now found in England mainly on the Yorkshire Wolds and, apart from its name, has lost all connection with its county of origin.

The **Devon Longwool** and the **South Devon** have never spread far from the counties of Devon and Cornwall.

All these Longwool English breeds have greatly decreased in both numbers and importance within recent times. Apart from specialised ram-breeding flocks, largely dependent upon an export trade, they are no longer a typical feature of the mixed husbandry of lowland England. For export they have lost a good deal of importance through the develop-

ment of their dual-purpose derivatives out of the Merino. The Longwool breeds have a magnificent historical past but a somewhat problematical future.

At least two Longwool breeds, however, the **Border Leicester** and the **Wensleydale**, are in a more secure position because they are widely used for crossing with hill breeds. In Scotland the Border Leicester is extensively used for this purpose alone. The first-cross with the Cheviot is the **Scottish Half-Bred**, probably at its best the ideal ewe for lowland temporary leys. The first-cross with the Blackface, called the **Greyface** or Cross ewe, is another useful sheep for lowland grazings. The Border Leicester also yields a good cross with both Herdwick and Welsh Mountain.

The **Wensleydale**, in the north of England, is used for much the same purpose as the Border Leicester in Scotland. Crossed with the Swaledale it produces the **Mule** or **Masham** Cross. Sheep breeders in the north of England are, however, rather more inclined to experiment with change of breed than is common in some other districts of Britain. Recently, another breed, the Blue-headed or Hexham Leicester, has tended to replace both the Border Leicester and the Wensleydale for crossing with the dark-faced hill breeds of the north. This Blue-headed Leicester is said to be an ancient breed of local origin, but its appearance rather suggests it to be a cross between Wensleydale and Border Leicester. In any case it is a Longwool breed of increasing popularity for cross-breeding.

The various crosses by Longwool rams out of hill ewes promise to become the predominant type of sheep on the temporary grasslands of lowland Britain. Their only serious competitors in England are two recently established breeds well suited to grassland farming, the **Kerry Hill** (Wales) and the **Clun Forest**. Both breeds originated on the English-Welsh border, and show clearly Welsh Mountain ancestry. Although pure bred they retain many of the valuable qualities of independence, foraging ability, hardiness, milkiness and prolificacy characteristic of the first crosses out of hill ewes. The Kerry Hill is a very attractive looking sheep with clearly defined black and white face markings. The Clun, a breed of ever-increasing popularity, resembles an in-bred cross between the Welsh Mountain and the Shropshire Down. It must be emphasised, however, that

while both Kerry Hill and Clun were probably formed by crossing a variety of lowland breeds, and perhaps other hill breeds, on the Welsh Mountain, with subsequent in-breeding and culling of the crosses, both are now firmly established as separate pure breeds with their own Flock Books and Breed Associations.

SHORTWOOLS

Many flocks of Longwools already described were kept under the old English folding system, but even more typical of the folded flock were the Down breeds, of which there is also a wide variety.

Down sheep are Shortwools, and the distinction between Longwools and Shortwools goes back to the earliest records of English sheep history. The Shortwool grows a typically short, fine fleece of light or medium weight, contrasted with the long, coarse, heavy fleece of the Longwool breeds. As the name indicates, Down sheep had their origin in the sheep that grazed the Downs, and historically speaking by far the most important of these was the breed that grazed the Southdown commons.

The **Southdown** was the first of the Down breeds to be improved towards better mutton conformation and earlier maturity. It was, in fact, the first English Shortwool to be cast into a modern shape. John Ellman, of Glynde, in Sussex, first made the attempt towards the end of the eighteenth century and his success was outstanding, the Southdown still being the butcher's ideal. To-day the Southdown is seldom, if ever, kept for the commercial production of mutton or of wool. Its purpose is to provide rams to pass on its superb mutton qualities to the fat lambs out of ewes of other sheep breeds. When quality of carcase is at a premium, then, to give the final top-cross in fat lamb production, the Southdown has no serious rival. In times of meat scarcity, however, the Southdown suffers in competition with other Down breeds which produce a larger and faster growing, if less perfect, cross lamb.

There are six Down breeds. Just as Bakewell's Improved Leicester was used to improve the mutton qualities of all the Longwools, so Ellman's Southdown was used on all the local breeds and varieties of Shortwools. The **Suffolk**

originated in a cross—in the first instance an accidental cross—between the Southdown and the ancient horned heath breed of Norfolk; the **Shropshire Down** by crossing the Southdown with the old heath breeds of Cannock Chase; the **Hampshire Down** by crossing with the original Shortwool type of that county. The **Dorset Down**, very similar to the Hampshire, owes even more to the Southdown. The **Oxford Down** has an origin rather different from the other Down breeds, having a great deal of Longwool—actually Cotswold Longwool—in its ancestry. It was founded as late as 1830 by the crossing of Hampshire rams on Cotswold ewes and by in-breeding the progeny.

The **Ryeland**, although white-faced in contrast to the dark-faced Down breeds, also owed much to the Southdown in its later history.

The **Dorset Horn,** a horned, white-faced Shortwool, stands rather apart from the other breeds of English sheep. It has a much more extended mating season and for this reason has been widely used for breeding out-of-season fat lambs. Some say it shows evidence of admixture with the Merino, which also has an extended mating season.

There are two other white-faced breeds in this country, the Wiltshire Horned and the Devon Closewool.

The Merino was at one time quite widely distributed in Britain and round about 1800 many experiments were made in its acclimatisation, indeed, there is a suggestion of the breed in England before Elizabethan times. There were in any case some noted Merino flocks in England far into the nineteenth century. The disappearance of the Merino from the English scene was due to English sheep-breeders, about 1800, turning their attention to mutton rather than to wool. The Merino, unrivalled for the quality and fineness of its wool, is not regarded as a mutton sheep. This fact, and the importation of more cheaply produced fine wool from newer continents and countries, caused the eclipse of the Merino in Britain.

BREEDING

Crossing is more prevalent in the breeding of sheep than in any other class of farm animal. The bulk of the world's sheep are cross-bred, which is not the same as being mongrel. Cross-bred sheep are the result of carefully planned breeding

systems; mongrels are the climax in a series of haphazard matings. The prevalence of cross-breeding in sheep is due to several reasons. Cross-breeding results in hybrid vigour, which means that the first cross between two distinct breeds is usually a better and more productive animal than either of its parents. This hybrid vigour vanishes when the first-crosses are in-bred, probably one reason why the first-cross is so widely used in commercial sheep farming.

Again, by a system of crossing, it is possible to secure a quick adaptation of sheep to pasture or arable conditions. For instance, whilst hill sheep are best fitted to the semi-natural conditions of mountain grazings, by crossing with a Longwool, the first-cross is suitable for cultivated pastures.

Crossing, moreover, allows advantage to be taken of the nutritional inequality of the natural seasons. To take a Scottish example, on the best class of heather-covered hills Blackface ewes are customarily mated with Border Leicester rams rather than with rams of their own breed. Such hills are suited only to Blackface sheep during winter, but in summer the pasture is fit to support something more productive. By crossing Blackface ewes with the bigger and more rapidly maturing Border Leicester, a cross lamb able to take full advantage of summer's bounty is secured.

Finally, crossing is the best method of obtaining an economical compromise between pastoral conditions and market requirements. Thus, while the Southdown undoubtedly provides the best mutton or lamb carcase, it would seldom, if ever, be profitable to maintain a flock for this purpose alone. The Southdown is rather delicate, is neither particularly milky nor prolific and under most pastoral conditions another breed or cross would thrive better. Thus the Southdown has become a ram-producing breed. Crossed with, say, Welsh Mountain or New Zealand Romney ewes the Southdown imparts much of its own mutton qualities to the progeny.

The advantages obtained by crossing may be carried into out-breeding within a breed. In many parts of the world—the Australian plains, the Scottish Highland hills—it is customary to bring rams from stud flocks in more fertile areas to "improve," as the saying goes, the range flocks of more barren grazings. The practice has the obvious danger of importing strains of sheep—either Merinos in Australia

or Blackfaces in the Scottish Highlands—too delicate for the range conditions their descendants must withstand. But the practice is so widespread in sheep husbandry that the compensating advantages must be considered. One such possibility is that when two different strains of the same breed of sheep are mated together, a certain degree of hybrid vigour may result.

Sheep of most British breeds—the Dorset Horn being the only important exception—have a definite mating season extending from autumn to spring. Ewes of these breeds will not take the ram during the summer months. Although the Dorset Horn is the only British breed which mates with any certainty during early summer, there are many other breeds throughout the world that do, of these the Merino is the most widespread and important. Even in these breeds, however, there seems to be a slackening in the intensity of mating during the summer. Long hours of sunlight inhibit the ductless gland secretions on which the sexual behaviour of the sheep depends.

Ewes of most British breeds come into heat during late August, September, and October. Heat in the ewe is not nearly so obvious as in the cow, and without the presence of rams it is usually impossible to tell which ewes are in heat. A ewe in heat gives off an odour that attracts the ram. The heat period is variable, extending on the average over about 30 hours. If the ewe is not put in lamb she continues to come in heat at intervals of about 16 days until the following spring. If conception occurs at mating, however, she does not come in heat again that season and lambs after an interval of about five months, more exactly 142–152 days, the average being 147 days.

A ewe may bear a single lamb or twins, twin births being much more frequent than they are in cattle. Triplets are quite frequent, and four, five or even more lambs at a birth are on record. In general, single lambs under range conditions and twins where husbandry is more intensive prove most profitable.

Fertility in sheep varies between individuals and between breeds. It is also greatly influenced by management. In general the better the pastoral conditions the more fertile the ewes, although it is possible for them to be too fat for breeding. When ewes are let down in condition before the mating

season—" tupping time "—and then, by better feeding, brought into rapidly improving condition to meet the rams, " flushing effect " is secured. " Flushing " ewes in this way raises their fertility, mainly by increasing the number of twins conceived. Fertility increases with age of the ewes up to about four or five years, after which it begins to decline.

The early progress of lambs depends upon the milking ability of the ewes. As with fertility milk yield in sheep varies as between individuals and between breeds. Considering it is of prime importance to the growth of lambs, knowledge of milk yield in ewes is scanty. As with dairy cows, " steaming up " before lambing by providing more and better food, leads to increased growth of the udder and a higher milk yield. After lambing the milk yield of the ewe depends upon her feed, changes in the condition of the pasture quickly affecting the milk yield of the ewe and, in consequence, the growth and bloom of her lamb. Ewes nursing twins give rather more milk than those nursing singles, a fact probably due to the greater number of times the ewe is milked daily.

In former times, indeed even to-day in the more primitive peasant communities of Europe and Asia, the sheep is used as a dairy animal, chiefly to supply cheese. Certain luxury brands of modern cheese are made from ewe's milk. As to quantity, most unspecialised sheep breeds average 20–30 gallons per lactation; milk yield in sheep, as in cattle, being considerably lower in the first lactation. Merino sheep, generally regarded as poor milkers, average about 21 gallons per lactation. In certain sheep breeds, specially bred for their dairy qualities, yields are much higher. Thus the East Friesian milch sheep yields over 100 gallons. Ewes' milk is richer than cow's milk, with a butter-fat percentage of 5·8 per cent. or even higher.

In sheep as in most other animals, the sexes are born in almost equal numbers. Whereas the majority of ewes are kept for breeding, the vast majority of male sheep are castrated as lambs, the castrated male sheep being called a wether. Wether sheep are used for the production of flesh or wool, or both. On the most barren sheep grazings, wethers can sometimes be kept profitably under conditions where, because of altitude, drought, exposure, or poor pastures, any attempt at breeding would meet with certain

failure. Under modern conditions of sheep husbandry, however, the great majority of wether lambs are slaughtered before they are one year old.

Male sheep left uncastrated or entire are used for breeding purposes. They are called rams or tups. The breeding and bringing out of rams for sale is usually left in the hands of specialist sheep breeders. The rams are most often pure-bred and pedigreed, and the main purpose of these ram-breeding flocks is to sell rams. Ram-breeding flocks are often called " stud " flocks. The ambition of a ram-breeder is to sell outstanding rams at high prices for use in other stud flocks. Less outstanding rams are sold to breeders aiming at mutton and wool production, these breeders being commercial sheep-breeders. Rams sold to commercial sheep-breeders, usually at more moderate prices, are used for mating with ewes of the same or different breed.

While rams are capable of sexual activity at most seasons of the year, there being no definite rutting season in sheep as there is in deer, the ram is usually most sexually active at the season ewes are in heat; in most British breeds from autumn to early spring. Hot weather definitely reduces their activity and may render them temporarily sterile. A ram under range conditions is usually allowed 30–60 ewes. Where ewes in heat are brought in to the ram, he may serve 100.

Artificial insemination has been used in sheep-breeding, particularly in Russia. The technique is closely similar to that widely employed in the dairy industry, the main difference being that, in sheep, teasers or vasectomised rams are required to detect ewes that are in heat. Teasers are rams of small value with an apron tied under them. Teasers follow and jump on ewes that are in heat but, because of the apron, cannot serve them. Vasectomised rams are those in which the vasa-deferentia, the tubes through which the semen pass from testicles to penis, have been severed. Vasectomised rams behave in every way like normal rams, but are sterile. On the whole, A.I. in sheep does not seem to offer the same commercial advantages as it does in dairy cattle.

PRODUCTS

The main saleable products of the sheep industry are mutton and wool. In some countries, Australia and South

Africa, for example, the main emphasis is on wool. In Britain, for more than a century, flesh has been of far more economic importance. New Zealand has achieved a nice balance in which the values of wool and mutton produced are roughly equal.

Mutton is less popular than beef as an article of diet and its consumption is confined mainly to sheep-breeding countries. As an article of international commerce the only really important market is the British Isles. Within the last 50 years there has been a trend to slaughter sheep at younger ages and at lighter weights. In fact, **lamb** rather than **mutton**, has become the most important and lucrative product of sheep-farming.

Wool remains the most important textile fibre for use as human clothing in temperate and cold climates. There are nowadays, however, many substitutes. Cotton, rayon, nylon and other types of artificial fibre closely resembling wool in some physical properties, have achieved increasing popularity. The effect of these substitutes has been to lower the price and limit the profitability of natural wool production. Nevertheless, particularly during wars and following wars, the growing of some types of wool meets a keen demand.

Not all sheep grow wool. Indeed, only half the world's sheep are wool-bearing. In Britain, the Wiltshire Horn breed grows no true wool. All other British breeds grow a fleece of some kind, the wool of different breeds being put to very different purposes.

Wool, considered as a raw material of the textile industry, may be divided into three main classes:—

(1) Fine or Merino wools.
(2) Cross-bred wools.
(3) Carpet wools.

The finest and most valuable wool still comes off the Merino sheep. The term cross-bred does not imply that the sheep from which the wool is shorn are necessarily cross-bred. It means that while the wool has not the fine quality of Merino wool, it can still be used for weaving cloth. The great majority of British breeds grow cross-bred wool. In many breeds, particularly Eastern, the wool is too coarse and hair-like for use in cloth making. It has, however, an

especial value in the making of carpets and rugs. Several British hill breeds, the Blackface, Swaledale and Herdwick, for example, produce carpet wools.

In the case of Merino and Cross-bred fleeces it has become customary to assess the fineness of the wool on a conventional range of figures called the Bradford Count. On this scale, the very finest Merino wools are classed as 100's or over. Most Merino wool is rather coarser, say 60's to 80's. The majority of cross-bred wools are classed in the 50's. Coarse longwools, such as Lincoln, may have a spinning count as low as 30's–40's. As well as fineness expressed in the spinning count, length of staple, soundness of fibre, yield and colour are all important qualities in assessing the manufacturing value of wool. A staple length of about two inches is required for the worsted trade, the most valuable branch of the wool textile industry. Soundness means that the fibre can be woven without risk of breakage. In some wool samples there is a point of weakness, called the break, in the fibres, due to malnutrition or sickness of the sheep at the time the weak section of the fibre has been grown. Yield expresses the proportion by weight of a fleece which is true wool. The fleece of every sheep when shorn contains a variable quantity of grease, dried sweat and extraneous dirt. When the fleece is scoured, all this foreign matter is washed out of the wool, and the weight of clean wool expressed as a percentage of the unscoured fleece is called the **yield.** Some wools, particularly those from some strains of fine-wooled Merinos, contain so much grease or yolk that the yield is little more than 50 per cent. The term colour as applied to wool means brightness and lustre. Dingy, stained or discoloured wools will not take the lighter and brighter dyes satisfactorily, with a consequent decrease in value.

MANAGEMENT

Sheep can be kept profitably under the most diverse conditions of husbandry. At one extreme is extensive sheep farming, where only one sheep may be grazed on a number of acres. This is typical of most dry or hilly sheep regions all over the world. The pasture is usually natural and uncultivated, the land cheaply rented, and the sheep live under semi-natural conditions. In Britain hill sheep farming is of this type and its success depends very largely on giving

the sheep plenty of space to roam and find a living. When sheep do well there is always a temptation to increase stocking, and overstocking is, perhaps, the most common error in hill sheep farming. This statement is particularly true of common grazings. Heavy mortality among hill sheep is often nothing more than Nature's method of correcting overstocking. Attempts to stock sheep closely on permanent pasture of any kind sometimes fails, because the land becomes "sheep-sick" owing to the accumulation of sheep parasites and disease germs. These results of close-stocking on permanent pasture are more quickly evident when sheep are grazed alone without cattle. On temporary leys sheep farming can safely become much more intensive. Stocking can be reckoned in *sheep to the acre* rather than in *acres to a sheep*. Fat lamb production from prolific and deep-milking ewes grazing good temporary leys is the most profitable system of sheep husbandry practised to-day.

The Folding System, in which the flock, closely concentrated, is confined between hurdles on specially grown arable crops was, until quite recently, the most common method of keeping sheep throughout lowland England. The system is falling into disuse, mainly owing to increased labour costs and the expansion both of dairying and grain growing in lowland areas. The Folding System was, nevertheless, an excellent method of keeping sheep, excellent both for the sheep and the land. It is possible that if cheaper methods of temporary fencing are devised, some revival of the Folding System might occur. The present indications are, however, that the most probable pattern of future sheep farming in Britain starts with the hill breeds. Crosses derived from these hill breeds will be used to stock temporary leys on lowland farms. These cross ewes on temporary leys will again be crossed by rams of a Down breed to give the type of fat lamb the modern consumer prefers. In aiming towards the final product—the Down cross "milk" lamb—other saleable produce of the country's sheep industry cannot be safely neglected. The wether side of both the hill flocks themselves and of their Longwool first crosses have to be sold for slaughter. Wool, even faced as it is to-day with the increased use of artificial fibre, should be something more than a mere by-product. The sheep industry, if it is to survive the competition of other forms of animal husbandry,

must produce readily saleable produce at every stage of its carefully graded descent from mountain to plain.

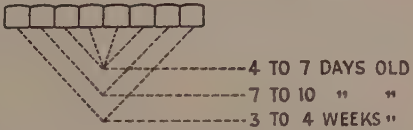
It is vitally important that the modern flock owner should give much more attention to the handling and care of wool. Whilst the breeder of rams and ewes must pay more attention to such qualities as hardiness, milk secretion and prolificacy.

FIG. 24—DENTAL FORMULA FOR A FULL MOUTH

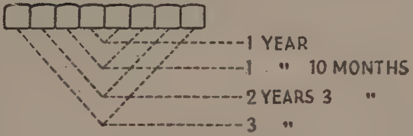
P.M.	T.M.	INC.	T.M.	P.M.
$^3/_3$	$^3/_3$	$^0/_4 \mid {}^0/_4$	$^3/_3$	$^3/_3 = 32$

TEETH AS INDICATIVE OF AGE

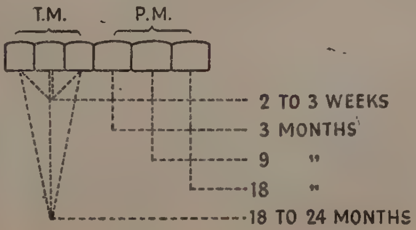
Appearance of Temporary Incisors



Appearance of Permanent Incisors



Appearance of Molars



ARTIFICIAL INSEMINATION

ARTIFICIAL insemination (A.I.) consists of collecting the male semen and inserting it at the appropriate time, that is, just before the egg is shed into the female tract.

During the last twenty years or so the technique has been applied in many countries as a means of livestock improvement.

Development has been extremely rapid and in some countries has outstripped the availability of suitable sires with which to apply the technique with any certainty of genetic improvement. A.I. is now widespread throughout the whole of Europe, America and Canada and is rapidly developing in many other countries of the world, including the East.

A.I. IN CATTLE

In Great Britain work started on a large scale in 1942. The development of egg-yolk dilutors, whereby semen could be diluted by as much as 300 times and still obtain normal fertility, meant large numbers of cows could be inseminated with semen from a single bull. It is not uncommon for a bull to sire 5000 offspring per year.

The responsibility for finding bulls of sufficient genetic merit to warrant such extensive use is obviously very great and the supply of such animals has fallen far short of demands. In order to be able to detect such animals the Milk Marketing Board has set up a Bureau of Records which collects data on the production of the daughters of all bulls. The performance of the daughters of any given bull are compared on a within-herd basis with that of all other bulls used in these herds. It is thus possible to iron out management factors to a large extent and to pick the best bull of the group.

The fruits of this work are only just being reaped and it is fortunate that it coincided with the development of the deep freezing technique of storing semen. By this means it is possible to store bull semen at $-79°$ C. for several years. Thus, semen from a genetically valuable bull, once he is detected, is made available to the whole country.

It is now, therefore, possible for any farmer to use any bull standing at any A.I. Centre to serve his cows. All that he needs to do is to have semen in the deep frozen form stored at his local Centre and notify them when his cows are ready for service.

Not only has deep freezing provided a national nominated service but it has now proved possible to despatch semen to any part of the world and to hold it in the receiving countries until required.

In many cases where foot and mouth disease may be a problem the semen is held until after the period of incubation and the donor animal is declared free of infection.

Semen treated in this way has been shipped to Australia and New Zealand and has given good fertility results several months after its collection in this country. The longest period of storage of frozen bull sperm at $-79°$ C. so far recorded is five and a half years.

In addition to this inter-centre link it is now also possible for breeders to have semen from their own bulls frozen and stored at A.I. Centres for use after the bull's death or for sale to other breeders.

Certain disease restrictions are imposed where sales of semen are made but these are not unreasonable and are merely to protect the purchaser.

The value of A.I. to the small dairy farmer is exceedingly great. The cows can be put in calf for approximately £1 per head without the cost of keeping a bull, and in addition for a small extra charge any bull in A.I. in the country can be nominated.

It is for these reasons, no doubt, that development has been so rapid and about two million cows are now inseminated annually in this country. All Breed Societies except one or two of the beef breeds welcome the technique and encourage their members to grade up by its use.

All Centres provide a service with beef bulls, usually Hereford and Angus and a farmer can cross the poorer yielding cows with a colour marking beef bull, using the better cows for breeding dairy replacements.

All A.I. Centres in Great Britain are under strict veterinary control and all bulls must be approved free from disease and of suitable pedigree and conformation. Control of these factors is vested in the Ministry of Agriculture.

A.I. IN HORSES

This is not carried out to any great extent outside the U.S.S.R., where it is largely used as a disease control measure. Stallion's semen cannot be stored satisfactorily for any length of time outside the body and it has proved extremely difficult to deep freeze.

A.I. IN PIGS

Experimental A.I. in pigs has been carried out for several years in Japan, U.S.A., U.S.S.R., Norway, Sweden, France and Great Britain, but the technique has only recently been put into practical application in this country.

Collection of semen presents no great difficulties, boars being readily trained to mount a dummy sow, but the semen does not store so well as that of the bull. It is diluted with a yolk/glycine diluent to a maximum of 1 part semen to 10 diluent and is stored at about 12° C. Although it retains activity for several days, fertility falls off sharply on storage. Like stallion semen it is extremely difficult to deep freeze.

Results of field trials have been disappointing, only about 35–40 per cent. of females farrowing to a single service. Litter size has been very satisfactory and it becomes obvious that the main problem is the detection of the onset of oestrus by the owner.

Unlike the cow, the sow sheds her eggs during oestrus and timing is, therefore, of great importance. The fact that when a pig becomes pregnant litters are normal in size suggests timing to be the main reason for the poor conception rates. It is also found that the larger herds with experienced pigmen obtain the best results.

A.I. IN SHEEP

Is practised largely in U.S.S.R., where some 28 million are inseminated annually. It is also practised experimentally in Australia and France and in these two countries results have only been satisfactory where fresh undiluted sperm has been used. After dilution and storage, results have been extremely poor despite the excellent activity of the sperm under the microscope. Similarly results obtained with

frozen semen have been extremely poor despite good activity after thawing out.

GENERAL PROCEDURES

Semen is collected by means of an artificial vagina consisting of a double walled rubber tube, the space between the walls being filled with warm water. The vagina is lubricated internally and the male animal allowed to mount either the teaser female which is placed in a service crate or else the dummy.

In the bull and ram ejaculation consists of a single thrust but in the stallion and pig the procedure is much more prolonged. This is particularly so in the boar, which produces about 250 c.c. in a single ejaculate. In the case of these latter two species the semen is mixed with a considerable amount of accessory fluid and contains a gel-like substance which has to be removed. In the boar this is done by filtering the semen through gauze.

In old and lame bulls it is possible to use an electrical method of collecting semen. This same method can also be applied very successfully to the ram.

The sample is then examined under the microscope to assess activity and if satisfactory is diluted with either yolk/citrate, yolk/phosphate or heat-treated milk (bull–ram) or with yolk-glycine (boar–stallion).

After dilution the sample is re-examined and then cooled until required for use.

The dosage inseminated varies from 0·5 c.c. (ram) to 100 c.c. (boar) and this is deposited either in the cervical canal or directly into the uterus of the female.

FARM POULTRY

POULTRY are economic converters of home grown foods into table eggs and birds and are considered seriously as part of most farms' general business.

The old time "barn-yard" hens had no special housing or feeding and the manure was mostly wasted round the steadings, but they provided for farmhouse needs and domestic pin money. Modern well-maintained farm poultry units can be one of the main profit earning enterprises on the farm and contribute to land management, soil fertility and pest destruction in addition.

Compared with specialist poultry farms where every outgoing must be charged directly against the birds, general farms offer many factors that the poultry can share. Part time supervision and labour, transport, rent, grazing and other incidentals give the birds certain financial advantages. Maintenance costs are relatively low and health standards high and given reasonable production profit should be assured.

Commercial egg production is the chief poultry objective, with table birds coming from cockerels surplus to pullet rearing and older hens as boilers as secondary sources of income. Breeding is largely left to specialists, since it demands particular skill and more time than can be spared on most farms. By purchasing day-old pullets from hatcheries or growing birds (to avoid heated appliance rearing) good laying strains can be obtained and the replacements will be birds hatched at the best times of the year to be profitable.

Clean land contributes materially to poultry health and profit. High mortality in the 1930's was largely due to heavy concentrations of birds kept continuously on limited areas. The consequence was a building up of parasitic infestations and harmful organisms that undermined stamina, making the stock vulnerable to various infections and epidemics, e.g., fowl paralysis.

By taking the poultry flocks round the farm both benefit, the droppings are more widely distributed and the risk of infection lessened. Ploughing after a period of poultry

occupation buries the manure, giving a gradually available supply of organic nitrogen, phosphorus and potash for the following crop, thus building up fertility. In this way the manure is utilised by cropping and better quality grass is produced for grazing or for carrying poultry again after some years.

Poultry are constant grazers where the herbage is fine, short and actively growing and the grass intake reduces other food requirements. On range they find animal, vegetable and mineral additions to the hand feeding, which lessen costs and promote health. The birds' scratching activity is useful—especially on old pastures—in tearing out mat and mosses, so allowing regrowth of the finer grasses. Insect pests are also kept down, notably wireworms.

Poultry can be kept on the land in mobile field houses (slatted or solid floors) holding 50 to 60 birds and moved in lines over the fields. Fold units (20 to 25 birds) controlling the birds within their runs are moved to constant fresh grass patches daily and require no night shutting. Sectional semi-intensive houses for up to 200 birds can be located about the grass land, and after a year or two, dismantled, removed and re-erected on a fresh field.

Feeding can be half home-grown grain—whole wheat, oats and barley in order of preference, or mixed—and half a laying meal mixture containing up to 15 per cent. protein (at least 5 per cent. animal protein) or whole grain and compounded balancer pellets. Water is usually carted, house moving and cleaning being undertaken at the same time. Water is given at the morning feed and eggs are collected after the evening meal. Kales, cabbages and roots are appreciated when grass is lacking.

One man can look after up to 1,500 birds kept in this way, provided it is his only work and he is given help with cleaning and transport. Seasonal work, such as rearing, must be done independently. It is important to have fully man-sized units or to limit the poultry when suitably housed and conveniently placed to just what can be looked after by part-time family labour.

If run at the same time or alternated with other grazing stock on permanent grassland, up to 150 birds to the acre are sufficient, but up to 250 per acre can be put on fields devoted entirely to poultry and ploughed after, say, two

years. A thousand adult birds will produce some 50 tons of rich manure yearly.

REARING

Since it is profitable to replace most of the laying flock each year, chick rearing needs special attention. The day-olds can be started in small outdoor heated brooders and go out on to good short grass swards that have been rested for 12 months. Chicks should not have access to ground used at any time by adult birds. The food can be cut or rolled farm cereals and rearing meal (later pellets) with about 15 per cent. protein content, also powdered or liquid milk, if available. White fish meal, with its high mineral content, is the best animal protein for poultry of all ages. Daily moves to fresh grass patches and control to prevent return to used sites is an important factor in health and growth.

After six to eight weeks the chicks can go to arks, folds or colony houses, standing, if possible, on a new ley, but in any case not on ground recently used by adult stock. The rule should be new birds to new land and no mixing of young and old. At four months of age they can be settled down in their permanent laying quarters.

The number of fowls kept in England and Wales in June, 1957, was approximately eleven million more than the corresponding period in 1939. The percentage of home produced eggs sold on the British market has increased from approximately 60 per cent. in 1939 to over 90 per cent. in 1957.

This big reduction in the import of eggs has been made possible by the most obvious reason of the big increase in fowls kept, and also to the improved efficiency of the breeds and cross-breeds kept.

The intensive systems of commercial egg production, deep litter, battery, give a more uniform production and reduce the labour charges, for one man can look after a greater number of fowl than on the extensive system, although a greater amount of capital is required for the accommodation of the intensive fowl. Treated on strictly business lines it is today a safer investment for anybody contemplating commercial egg production as distinct from breeding. It is

essential for such a venture that the attendant or director, or better still both, should have a sound knowledge of the right breeds or cross-breeds which will respond to such a system; a thorough knowledge of housing, which means ventilation, light, and the number of fowls a given size house can accommodate. A thorough knowledge of the nutritional requirements of the fowls, and lastly a thorough knowledge of all poultry diseases, their prevention and detection, and in some cases treatment, for where a large number of fowls are so concentrated the risk of the spread of disease is far greater than when they are spread over a wide area.

HOUSING

Batteries—Single laying cages with wire floors in which each bird has its own food and water, are arranged in groups, three tiers high in large fixed buildings suitably lighted and ventilated. The cost of cages, housing, lighting and in some cases mechanical cleaning and feeding is higher than with any other method, but so are the returns, especially in winter eggs. Cod liver oil at 1 to 2 per cent. must be continuously in the food.

Intensive Houses—Large, glass-fronted houses, with perches over pits or boards and deep litter floors accommodate one bird per 3 sq. ft. of floor space intensively. Very small outdoor runs, if any, are used, or wire floor run parlours. High winter production can be maintained, and dry mash or pellets are generally fed from hoppers always before the birds and grain in the scratching litter.

Hen Yards—A combination of perches over pits for droppings and laying places under cover with deeply strawed open yards, provide cheap laying quarters where existing buildings can be adapted. Laying meal or pellets are fed in troughs under the covered section and grain in the strawed yard. This gives exercise and breaks up the litter to which more straw is constantly added.

In none of these methods do the birds benefit from grazing and other fresh natural food, so the feeding must contain dried grass meal, vitamins and mineral mixtures in compensation.

Intensive Rearing—First stage indoor chick rearing is useful for winter work and where large numbers are reared

over a long season. Long brooder houses are sub-divided for unit numbers and successive hatches, each compartment with its own hover, being heated by oil, water or electricity and approached from the attendant's gangway. The chicks are on litter and possibly allowed out on wired floor sun balconies, but have no access to the grass or ground. Tier or battery brooding is another form of intensive first stage rearing, the chicks being on small mesh wire floors, with the sleeping compartment heated above or below and the run portion fitted with outside feeders and drinkers accessible through barred grids. At about three weeks the chicks are usually moved into cooler cages and to floor brooding at about five weeks old. Feeding has to be specially designed to permit this intensive rearing, and must include cod liver oil and all vegetable, vitamin, grit and mineral needs.

It is generally agreed that for all subsequent purposes, the growing period from about eight weeks to approaching maturity should be spent outside on grass, in fold units or in large pens.

DUCKS AND GEESE

A few ducks for both table and eggs can find a place on most farms, but large flocks are too costly to feed unless they find much free food ranging widely over suitably moist land and water. Khaki Campbells combine laying and table qualities; Runners are layers and Aylesburys the finest table birds for quick growth and flesh quality. Production of first class ten week ducklings is highly skilled work.

A breeding trio of geese is easy to maintain and profitable, there being goslings for sale and a limited number of table birds. Flocks of geese must have suitable short grass range —such as common land—as they can then live most of the year by grazing. Embdens, Toulouse and the cross between them are the best large breeds, with Roman and Chinese as lighter birds and better layers.

POULTRY BREEDS

Leghorn—*Varieties*: White, Black, Brown, Buff, Cuckoo, Pule. *Classification:* Light breed. *Type of Comb:* Large single. *Colour of Flesh and Skin:* Yellow. *Colour of Legs and Feet:* Yellow. *Colour of Egg Shell:* White. *Country of Origin:* Italy.

Ancona—*Varieties:* One (Black and White). *Classification:* Light breed. *Type of Comb:* Large single. *Colour of Flesh and Skin:* Yellow. *Colour of Legs and Feet:* Yellow mottled with black. *Colour of Egg Shell:* White. *Country of Origin:* Italy.

Minorca—*Varieties:* Black, White. *Classification:* Light breed and Exhibition. *Type of Comb:* Large single. *Colour of Flesh and Skin:* In White, White, Black, Grey. *Colour of Legs and Feet:* In White, White, Black, Dark Slate. *Colour of Egg Shell:* White. *Country of Origin:* Spain.

Rocks—*Varieties:* Barred, White, Buff. *Classification:* Exhibition, Dual Purpose. *Type of Comb:* Medium single. *Colour of Flesh and Skin:* Yellow. *Colour of Legs and Feet:* Yellow. *Colour of Egg Shell:* Brown. *Country of Origin:* America.

Wyandotte—*Varieties:* White, Black, Silver-laced. *Classification:* Exhibition, Dual Purpose. *Type of Comb:* Rose. *Colour of Flesh and Skin:* Yellow. *Colour of Legs and Feet:* Yellow. *Colour of Egg Shell:* Light to dark brown. *Country of Origin:* America.

Rhode Island Red—*Varieties:* Rose Combed, Single Comb. *Classification:* Exhibition, Dual Purpose. *Type of Comb:* Single Comb, Medium and Rose. *Colour of Flesh and Skin:* Yellow. *Colour of Legs and Feet:* Yellow or reddish yellow. *Colour of Egg Shell:* Brown. *Country of Origin:* America.

New Hampshire Red—*Varieties:* One. *Classification:* Dual Purpose. *Type of Comb:* Medium single. *Colour of Flesh and Skin:* Yellow. *Colour of Legs and Feet:* Yellow. *Colour of Egg Shell:* Brown. *Country of Origin:* America.

Sussex—*Varieties:* Light, Red, Brown, Buff, White. *Classification:* Exhibition, Meat, Dual Purpose. *Type of Comb:* Medium single. *Colour of Flesh and Skin:* White. *Colour of Legs and Feet:* White. *Colour of Egg Shell:* Tinted. *Country of Origin:* England.

Orpington—*Varieties:* Black, Buff, White. *Classification:* Exhibition. *Type of Comb:* Medium single. *Colour of Flesh and Skin:* In Black, Grey, all other varieties, White. *Colour of Legs and Feet:* In Black, Black, all other varieties,

White. *Colour of Egg Shell:* Tinted. *Country of Origin:* England.

Cornish or Indian Game—*Varieties:* Dark, White, Red. *Classification:* Exhibition, Meat. *Type of Comb:* Pea. *Colour of Flesh and Skin:* Yellow. *Colour of Legs and Feet:* Yellow. *Colour of Egg Shell:* Mainly White. *Country of Origin:* England.

Barnvelder—*Varieties:* Gold-laced, Partridge, Black. *Classification:* Dual Purpose. *Type of Comb:* Medium single. *Colour of Flesh and Skin:* Yellow. *Colour of Legs and Feet:* Yellow. *Colour of Egg Shell:* Dark Brown. *Country of Origin:* Holland.

Cambridge Breed or Auto-sexing Breeds—These breeds come under the heading of pure breeds. They were produced by crossing a non-barred breed with a barred breed for a number of generations in a certain way. Sex distinction is seen in the colour of the down of the chicks. The **Legbar** is one of the commonest of the Cambridge breeds, and the parent breeds are the Brown Leghorn and the Barred Rock.

Hybrids—This group of poultry are produced by crossing two closely in-bred strains. The ability to convert food into eggs is very high. They are of no value for meat production. For commercial egg production a first cross between a Light and a Dual Purpose breed is greatly favoured. WL × RIR, BL × RIR are good crosses provided a good strain of the parent breeds is used. The chicks of the above cross have to be sexed by the vent method. There are some crosses which are known as sex-linked crosses, that is the sex of the chicks of such a cross can be determined at a day old by the colour of the down. For such determination a cock of the gold group of breeds must be mated to a hen of the silver group of breeds.

Gold Group of Breeds—	Silver Group of Breeds—
Brown Leghorn	Light Sussex
Rhode Island Red	White Wyandotte
New Hampshire Red	All breeds with the prefix "silver"
All breeds of a brown or gold colour	

(The White Leghorn is not a silver breed.)

Sex linkage can also be obtained by crossing a black cock with a barred hen. This cross is not as easy to distinguish as the gold and silver cross.

In each of these crosses the resulting pullet chick takes on the colour of her sire, whilst the cockerels take the colour of their dams.

TURKEYS

The breeds of turkey can be grouped according to size. The *American Mammoth Bronze*, the *Broad Breasted Bronze* and the *Broad Breasted Whites* are the three larger breeds, mature stags weighing from 30–35 lb., mature hens from 16–20 lb. The medium breeds are the *Norfolk Black*, *Austrian White*, *British White* and *Buff*, mature stags weighing from 18–24 lb. mature hens from 12–14 lb. The *Beltsville White* is the smallest of the breeds, mature stags weighing from 14–16 lb., mature hens from 8–9 lb.

The weight within each breed is only a guide, for these weights can be increased or decreased according to the size of breeding stocks selected.

A breeding pen consists of from 8–10 hens to one stag. Normally the hens will commence to lay in April, and if not allowed to incubate their own eggs will continue to lay until July or August, although frequently the eggs laid during August may be infertile due to the stag moulting. The period of incubation is from 26–28 days. The eggs can be successfully hatched artificially.

The young poults are reared the same way as young chicks with the addition of from 2–3 per cent. protein in their mash. Particular attention must be paid to the vitamin and mineral content of the mash. They do appreciate green food in the form of cabbage or kale, and if these are not available then 5 per cent. of a good quality grass meal should also be included in the mash.

The most profitable time to market them is at from 20–24 weeks of age, for at this stage the food convertion ratio will be 1 to 4 or 1 to 4·5. If not marketed at this stage the food convertion ratio may be 1 to 5 or 6.

Turkeys are subjected to all diseases of ordinary chickens. Apart from any deficiency disease, Blackhead and Coccidiosis are the two commonest diseases of growing turkeys.

TABLE CHICKENS

The main demand for table birds is for chickens weighing from 4–5 lb. live weight, with the exception of the Christmas season, when a chicken of from 7–8 lb. is favoured. A great number of the 4–5 lb. chickens are produced in small units as a by-product in the production of pullets. This is very seasonal production, from May to August. If the consumption of such chickens is to be further encouraged then a steady flow must reach the market all the year round. This is being done by the broiler industry; which is a highly specialised branch of table poultry production.

The name *Broiler* is of recent introduction and is sometimes confused with the word *Boiler*. *Broiler* is the name given to a young chicken weighing from 4–5 lb. at 12–14 weeks of age. *Boiler* refers to an old fowl of over nine months of age.

No one should embark on the production of broilers without careful planning, particularly with regard to marketing, since the chickens must be sold at 12 weeks. If kept over that age by many weeks, they are likely to be unprofitable. The enterprise must be organised to have the contracted number ready for marketing weekly. The breed, or cross-breed, should be carefully considered.

In this country white flesh is favoured, hence the Light Sussex seems the best pure breed to use and also as one of the parent breeds for crossing. The Brown Leghorn and New Hampshire Red crossed with the Light Sussex give a white-fleshed, quick-feathering and early maturing chicken. Early maturity and quick feathering are important factors as the chicks are kept intensively in limited space. If slow-feathering there is a great risk of feather-pecking, which frequently leads to cannibalism and loss of chicks.

Feeding—The chicks are fed on a very stimulating mash from start to the time of marketing, the inclusion of antibiotics and anti-coccidiosis drugs in the mash being a common practice. They must be carefully managed in order to avoid any check to their progress. Under such conditions, for each $3\frac{1}{2}$ lb. of food consumed, 1 lb. of live-weight increase should be obtained, giving a conversion ratio of $1 : 3\frac{1}{2}$. Cockerel chicks are the most favoured for Broilers as they grow quicker than pullets.

Housing—The house should be well-ventilated, free from draughts and having a floor space of 1 sq. ft. per chick. The cost of accommodation, which includes house, rearing equipment, etc., for the production of 100 Broilers per week, is from £900 to £1000.

The demand for heavy chickens (7–8 lb.) is confined mainly to the Christmas season. Such chickens can be hatched in May, June or July, placed on free range at six weeks of age, so as to grow naturally, and produce a good strong body. The Indian Game × Light Sussex or the Rhode Island Red × Light Sussex are good for the production of these heavier birds. At about 16 weeks of age they become sexually mature and the quality of the flesh deteriorates from this stage. In order to retain the quality flesh of the young immature bird therefore it is the practice to caponise them at from 12–16 weeks old. The male reproductive organs need not be removed as with the old system, but the growth of the male organs are retarded by implanting in the neck of the cockerel a small tablet (15 mgm.) of stilboestrol. Such chemical caponising can be carried out by most people after a little practice. Caponised birds become docile, losing the restless and aggressive character of the male. They may not grow larger than their inheritance, but the flesh becomes more abundant, tender and juicy. One implantation usually lasts for about eight weeks and they may need a second implant when the effect of the first wears off. It is not advisable, however, to implant the cockerels within one month of killing time.

ANIMAL NUTRITION

THE science of nutrition involves the study of the chemical and physiological processes necessary for the conversion of food constituents to body constituents and body products, for the provision of energy to bring about this conversion and for the muscular and other activities of the animal.

Plants, which almost exclusively furnish the food materials of farm animals, build up under the influence of sunlight complex compounds from carbon dioxide, water and mineral salts. In the animal these compounds are broken down to provide body building materials and energy.

- **Plants**
  - (*a*) **Water**
  - **Dry matter**
    - **Organic matter**
      - (*c*) **Nitrogenous substances**
        - **Protein**
        - Non-protein Nitrogen (amides)
      - (*d*) Fats, Oils and associated compounds (ether extract)
      - (*e*) Carbohydrates
        - Nitrogen free extractives (soluble carbohydrates)
        - Crude fibre
      - (*f*) Vitamins
    - (*b*) **Inorganic matter** (mineral matter or ash)

The same or similar substances occur in the animal body but in different proportions.

Water is the principal component of plants and animals. In plants it comprises 70–90 per cent. by weight of grass, silage, kale, and other green crops and roots. There is between 10 and 20 per cent. of water in dry foods such as the cereal grains and roughages. The amount present in plants decreases as the plant matures.

In the animal body the percentage of water decreases

rapidly in early life but more slowly as maturity is approached when it contains 50–60 per cent. of water, the amount present being influenced by the nutritional state as shown by the fat stored. Thus a fat animal contains less water than a lean one.

The amount of fat present in the animal body varies with the plane of nutrition and, in general, increases with age. Species such as the horse and the fowl may contain as little as 17 to 19 per cent., the pig about 25 per cent. and the steer as much as 33 per cent.

Most species with the exception of the fowl (21 per cent.) contain between 15 and 17 per cent. of protein; in addition about one per cent. of carbohydrate, actively concerned in the metabolic processes, is usually present. The mineral matter roughly reflects the size of the skeleton and ranges from 2·8 per cent. in the pig to 4·6 per cent. in the steer.

Fat shows the greatest amount of variation, thus causing variations in the amounts of the other constituents. When the composition of the animal body is expressed on a "fat-free" basis the gross composition of the body in respect of the other constituents becomes much less variable and is approximately 75 per cent. water, 20 per cent. protein and 5 per cent. mineral matter. Little deviation from these figures is evident after maturity is reached although the water content decreases throughout life.

The groups of chemical substances of which the animal body is composed tend to be localised according to the functions they perform. Although water is a component of all parts of the body, its distribution is variable. Thus blood plasma contains 90–92 per cent. of water, muscle 72–78 per cent. and bone 40–50 per cent. Carbohydrate is centred chiefly in the liver, muscles and blood; proteins are present in the organs and soft body structures such as muscles, tendons and connective tissues, and fat subcutaneously and around the intestines, kidneys and other organs. The mineral matter is also widely distributed, the individual minerals being localised according to their function. With the exception of calcium the mineral elements occur as fractions of one per cent. Eighty per cent. of the total body phosphorus is present, combined with calcium, in the skeleton while the remainder is found in association with proteins, fats and inorganic salts. Most of the magnesium is present

in the bones, the remainder being widely distributed. Sulphur is present as part of the protein molecule while sodium, potassium and chlorine are found as inorganic salts, sodium and chlorine being inter-cellular and potassium intra-cellular. Although some minerals have been shown to be necessary for life others have no known function.

The protein of plants occurs in the active tissues and leaves are therefore richer in protein than stems. As the plant approaches maturity there is a gradual transition of protein from leaf to seed to provide for growth requirements at germination.

Most seeds, for example the cereal grains, contain carbohydrates as a reserve source of energy; in others such as oil seeds fat is the form in which energy is stored. Normally the leaves contain more fat than the stems but the amount is highest in the seeds.

In addition to acting as a reserve material principally as starch, carbohydrate in the form of cellulose may function as a structural or protective element.

The Mineral Matter (ash) of plants varies with the species, with individual plants of the same species and with the parts of the plant. It may be markedly influenced by soil factors. Plants are richer in potassium than in other elements, the amounts of calcium and phosphorus being considerably less. Calcium is associated with the vegetative parts of plants hence leaves are richer than stems. Seeds are the poorest source of calcium although oil seeds contain more than others. In the case of phosphorus, seeds are richer than leaves and leaves are a better source than stems.

WATER

Water performs a number of important functions in the animal body. As a solvent it is concerned in the transportation of solutes which include products of metabolism. It is connected with the mechanisms of secretion and excretion. Large quantities of water are involved, for example, in the secretion of saliva during mastication. Water is an important constituent of the lubricant of joints and acts as a cushion for the nervous system; it is also associated with the senses of seeing and hearing. The high specific heat of water enables it to absorb large quantities of heat for correspond-

ingly small increases in temperature. This is one means by which the temperature of the animal body is regulated. Another is the result of its high latent heat of vaporisation and evaporation from the skin helps to cool the body.

SOURCES OF WATER

Most of the water utilised is ingested but further supplies are released during metabolism. The oxidation of carbohydrate liberates water in addition to carbon dioxide and energy.

Fats and proteins also release water in this way. This metabolic water is sufficient to meet the requirements of hibernating animals for water lost in respiration and evaporation. Water is also required for the formation of tissues during growth and for productive purposes, e.g., milk secretion and egg production.

It is excreted via the urine where it acts as a solvent for such catabolic products as urea and minerals; some is removed from the body in the expired air as water vapour while the remainder is lost in perspiration. The latter loss, via the sweat glands, is a mechanism for the regulation of body temperature since heat is dissipated in the evaporation of water.

WATER REQUIREMENTS OF ANIMALS

The amount required by any animal must be sufficient to balance the losses outlined above and to allow for the formation of new tissues and body products.

It has been shown that milking cows require 4–5 lb. water for each 1 lb. milk produced and it is evident that all livestock should have adequate supplies of water at all times.

THE CARBOHYDRATES

These are widely distributed in plants and although forming the largest part of the food of animals only small amounts of sugars and glycogen occur in the animal body. They are produced by photosynthesis, a process occurring in green plants whereby with solar energy carbon dioxide and water are chemically combined. They owe their name

to the fact that they contain carbon which is combined with hydrogen and oxygen in the same proportions as in water.

The chemical energy of the carbohydrates can be liberated by the plant for its own use or by an animal using it as food material.

Glucose, though not the primary product of photosynthesis, is perhaps the best known of the simple sugars and from it other carbohydrates are formed. These include the *Pentoses* arabinose, xylose and ribose, and *Hexoses* such as fructose. Carbohydrates of these types are known as *Mono-saccharides.*

When glucose combines with fructose cane sugar or sucrose is formed and when two molecules of glucose combine the resulting sugar is maltose. These carbohydrates are known as *Di-saccharides.* The combination of numerous molecules of glucose results in the formation of starch; cellulose is formed from a different type of glucose. Starch and cellulose are *Polysaccharides.* The formation of di- and poly-saccharides involves the elimination of water (condensation); under suitable conditions these complex non-sugars can be broken down to their simple constituents by the addition of water (hydrolysis).

Glucose (dextrose or grape sugar) and fructose (laevulose or fruit sugar) are present in fruit juice and honey and are the only members of the group to occur free in nature. Galactose is formed from the hydrolysis of lactose (milk sugar).

Sucrose or cane sugar is present in sugar cane, sugar beet, ripe fruits and tree sap (maple sugar) and is the source of domestic sugar. It cannot be directly absorbed from the intestines and in digestion is broken down to glucose and fructose. The non-crystallisable sugar obtained as a liquor from the refining industry is known as molasses.

Maltose is produced by the hydrolytic action of diastase on starch and, during digestion, is hydrolysed to glucose by the enzyme maltase.

Lactose occurs only as a product of the mammary gland and comprises approximately half the solids present in milk. On hydrolysis it yields glucose and galactose, compounds of the latter sugar occurring in the brain and nervous tissue. Lactose, which possesses a number of physiological

advantages over other sugars, is less sweet and less soluble than cane sugar.

Starch forms the reserve material of most plants, the starch granules of different plants varying in size and shape. On hydrolysis by acids or enzymes dextrins, maltose and glucose are successively yielded. It is widely distributed in tubers and cereal grains and gives a characteristic blue colour with iodine. In certain plants, e.g., the Jerusalem artichoke, it is replaced as reserve material by inulin which yields fructose on hydrolysis. Glycogen or " animal starch " is present in the liver and muscles. It closely resembles starch in properties and functions and, like starch, yields glucose on hydrolysis. With iodine it gives a brown coloration.

Cellulose is a structural carbohydrate and as such is associated with lignin in the framework of plants and in the protective coating of seeds. It can be hydrolysed by strong acids to glucose but is not acted upon by any enzyme secreted by the digestive systems of mammals. It is however broken down by micro-organisms in the digestive tract of certain animals. Lignin, although containing carbon, hydrogen and oxygen, is not a true carbohydrate but it occurs in intimate association with cellulose and is included with carbohydrates in the conventional methods of analysis. The presence of lignin has a considerable influence on the digestibility of certain foods.

SOLUBLE CARBOHYDRATES AND CRUDE FIBRE

In the chemical determination of the carbohydrates two groups are recognised: (*a*) Soluble carbohydrates or nitrogen-free extractives, and (*b*) Crude fibre. They appear under these headings in tables showing the gross composition of feeding stuffs.

Soluble carbohydrates include sugars, starch and hemicelluloses; this fraction is not actually determined but represents the difference between the sum of all other constituents (water, ash, crude protein, ether extract and crude fibre) and 100.

Crude fibre includes cellulose, pentosans, lignin and cutin (a substance which prevents excessive evaporation of water from, and the entrance of excessively large amounts of

water into, plants). This fraction is higher in hay and foods classed as "roughages" than in cereal grains. Similarly it is high in milling offals such as bran and other seed or cereal by-products than in the seed or grain as a whole.

The function of carbohydrates is to provide energy on oxidation, surplus supplies being converted into reserve fat. Unless carbohydrates are present in adequate amount, protein, a much more expensive nutrient, is oxidised instead. Furthermore, although much of the crude fibre is indigestible, it adds bulk to the ration and thereby satisfies the appetite and stimulates peristalsis. In addition it may assist the digestion of certain concentrated foods which would otherwise tend to form "doughy" masses in the stomach impenetrable by the digestive juices.

GLUCOSIDES

These substances which contain glucose are important, not as nutrients but by reason of their toxic properties by which plants are provided with protection. Two main types are recognised, Cyanogenetic glucosides and Mustard oil glucosides.

The former liberate (amongst other products) hydrocyanic acid or prussic acid on hydrolysis. Linseed for example liberates the cyanogenetic glucoside linamarin and, when the crushed seed is kept warm and moist, the glucoside is hydrolysed yielding prussic acid. Care must therefore be taken to use boiling water in the preparation of linseed gruels or to boil the gruel for about 10 minutes.

Glucosides of the second type contain an irritant, allyl isothiocyanate "essential oil of mustard" and occur in black and white mustard seeds. While the whole seeds may pass through the digestive tract without harmful effect yet, as crushed impurities in cakes, they have proved toxic.

FATS AND OILS

These belong to a group of compounds known as lipides. They are widely distributed in plants and animals and quantitatively represent the most important constituent of the animal body. They are insoluble in water with which they form emulsions but soluble in ether, chloroform and benzene. In the conventional analysis of foods these solvents remove sterols and other compounds related to the

fats. For this reason the extracted material is known as " crude fat " or " ether extract."

Fats and oils are mixtures of compounds of glycerol and various fatty acids. A triglyceride is obtained when a molecule of glycerol combines with three molecules of a fatty acid. As there are many fatty acids a wide variety of triglycerides and therefore of fats is possible.

Fats, like carbohydrates, contain carbon, hydrogen and oxygen but the amount of oxygen present in the molecule is relatively small and, weight for weight, they yield considerably more energy.

There is no essential difference between fats and oils. The term oil is used for a fat that is liquid at ordinary temperatures; certain oils in fact solidify in winter.

The molecules of the fatty acids present in the harder fats contain relatively more hydrogen than those of the softer fats. The former are called " saturated " and the latter " unsaturated " fatty acids. Fat consistency depends on the nature and proportions of the fatty acids present since these have different melting points.

Comparatively hard fats such as beef and mutton fat contain palmitic and stearic acids with melting points of 63° C. and 70° C., while softer fats such as lard and butter have a higher proportion of unsaturated fatty acids, i.e., acids which are liquid at ordinary temperatures. Butter frequently becomes more oily when cows first go out to graze in spring due to an increase in the amount of oleic and linoleic acids consumed. Linseed, rape and other oils contain a high proportion of oleic acid so that stall-fed animals receiving large quantities of such cakes as linseed and rape may produce butter of an oily consistency. Conversely palm oil, a constituent of palm kernel cake, produces a firm butter by reason of its content of palmitic acid.

USES OF FATS

Oils from oleaginous seeds used in the preparation of cattle cakes, and fats unfit for human consumption (from slaughter houses) are hydrolysed by heating with caustic soda or caustic potash. The process, which is known as saponification, is important in the manufacture of soap and glycerine.

Margarine-making involves the catalytic hydrogenation of

mixtures of vegetable and animal fats to increase the degree of saturation of the fatty acids and produce a harder product. The vitamin content is then increased to the same standard as that of good butter.

IODINE NUMBER

Iodine can also be used to saturate fatty acids and the weight of iodine which can be absorbed by a given weight of fat provides a useful measure of the character of that fat. Foods which contain fats or oils with a high proportion of unsaturated fatty acids will tend to produce soft carcase fat, e.g., soya bean oil has an iodine value of 130 and soya beans give rise to very soft bacon fat. A change of diet, involving a change from foods rich in unsaturated fats to foods rich in saturated fats causes a modification of the carcase fat deposited.

In addition to the Iodine Value there are a number of other constants the difference in values of which afford means for the identification of oils. This is of assistance in detecting adulteration, e.g., the adulteration of butter with margarine containing vegetable oils.

RANCIDITY

Small amounts of free fatty acids may be present in foods, particularly in immature, growing plants. Foods which have been stored in a damp condition or which have absorbed moisture on storage tend to undergo certain changes which result in the development of unpleasant odours and tastes, i.e., they become rancid.

While the development of rancidity may be oxidative in character it can also be caused by certain fungi and micro-organisms. Usually it involves the hydrolysis of fats and oils, by the enzyme lipase, with the production of free fatty acids. Butter becomes markedly rancid after only mild hydrolysis. The comparative ease with which rancidity may develop emphasises the need for careful storage of animal foods containing fat or oil.

THE PROTEINS

Protein is the principal constituent of the organs and soft body structures and food protein is the only source of

tissue protein. It is therefore essential to avoid dietary deficiencies.

The feature which distinguishes proteins from fats and carbohydrates is the high and fairly constant nitrogen content, usually between 15 and 18 per cent. Some proteins also contain phosphorus or sulphur.

Proteins are complex compounds formed by the combination of amino acids, 22 of which are known to occur in typical food protein. As there are about 25 amino acids a great variety of proteins results. Proteins form colloidal "solutions"; some are insoluble. Their properties depend on the arrangement and nature of these amino acids and on the number present. They are classified according to their physical characteristics into first, *Simple Proteins*, of which the albumins, globulins and scleroproteins are examples; secondly, *Conjugated Proteins*, such as phosphoproteins, chromoproteins and nucleoproteins, and thirdly, *Derived Proteins*. The proteins of this group are simpler in character than those from which they have been produced, e.g., casein of curdled milk.

Lactalbumin and lactoglobulin are examples of simple proteins which occur in milk. Scleroproteins are typical of skeletal structures and protective tissues and include ossein of bone and collagen of hoof and horn. Caseinogen and ovo-vitellin, the chief proteins of milk and egg yolk respectively, are phosphoproteins, the principal form of food protein of young mammals and chick embryos. Chromoproteins are proteins combined with a coloured group. Haemoglobin, of blood, consists of the protein globin combined with haematin. Nucleoproteins, which are characteristic of cell nuclei, consist of protein combined with nucleic acids.

MINERAL CONSTITUENTS

The inorganic elements, which in the conventional analysis of feeding stuffs are represented by "ash," occur partly in inorganic form and partly in organic combination. Adequate supplies are essential for the formation of bones and teeth and to give strength and rigidity to skeletal structures. They are necessary also for the formation of blood and other body fluids the pH and osmotic pressure of which they regulate. They are constituents of muscles, organs

and other soft tissues, and are concerned in the relaxation and contraction of the heart muscle. Some elements are actively concerned in metabolism and in the control of the metabolic rate. Growth, fattening and production of body products involve the utilisation of mineral elements.

Certain of the elements are inter-related and may conveniently be described together.

Calcium and Phosphorus together form 90 per cent. of the ash weight of the animal body, about 98 per cent. of the calcium and 80 per cent. of the phosphorus being present in the bones and teeth. Bones contain about 50 per cent. water, 5 per cent. fat, 20 per cent. protein and 25 per cent. ash, while bone ash is composed of approximately 85 per cent. tri-calcium phosphate, 14 per cent. calcium carbonate and about 1 per cent. magnesium phosphate.

Although there may be slight variations with age and diet, calcium and phosphorus usually occur in a 2 : 1 ratio.

Calcium salts are also essential for the clotting of blood, the level of blood calcium being regulated by a hormone secreted by the para-thyroid gland. Calcium also plays a part in the clotting of milk. Phosphorus is a constituent of the blood and of nucleoproteins and has an important role in carbohydrate metabolism.

The growth of bone involves the conversion of cartilage to protein (ossein) which is mineralised chiefly by calcium and phosphorus.

Milk contains large quantities of these elements and when the demand for them, e.g. during pregnancy or lactation, is great supplies are supplemented by withdrawing them from the spongy bones. Demineralisation of the spongy bone can occur without harmful effect and when the demand for calcium and phosphorus decreases, e.g., as lactation declines, the bones are re-mineralised. When, in the adult animal, a dietary deficiency of these elements occurs in combination with a vitamin D deficiency even the compact bone may become involved. If the deficiency persists the bones lose rigidity and osteomalacia develops. In young animals deficiencies of calcium and phosphorus, or vitamin D, retard the development and mineralisation of bones and lead to rickets. Milk fever in dairy cows, the result of a fall in the level of blood calcium which may occur at the beginning of

a lactation, is cured by the injection of soluble calcium and magnesium salts.

The ability of farm foods to meet the animal's requirement of these elements differs; roughages are rich in calcium but poor in phosphorus while the reverse is the case with cereal grains. Pastures differ in their content of these elements but good pastures, especially those containing leguminous plants, are useful sources.

While adequate amounts of calcium and phosphorus in foods are necessary, the proportion in which they are present is at least as important. A ratio of about 1–2 Ca : 1 P and most probably 1·5 Ca : 1 P appear to be the optimum; any marked deviation from these figures leads to a disturbance of their absorption.

Sodium, Potassium and Chlorine compounds are found almost entirely in the soft tissues and blood. The body contains about 0·2 per cent. sodium, chiefly in extra-cellular fluids, and slightly less potassium. Sodium, which forms over 90 per cent. of the bases present in blood serum, is not stored in the body to any extent and is eliminated in the urine, as chloride or phosphate, and in perspiration.

Deficiency of sodium results in retarded growth and inability to make full use of digested carbohydrate and protein.

Foods of animal origin are better sources of sodium than those of plant origin while the reverse is true of potassium. Hence a dietary deficiency of potassium is unlikely to occur. Compounds of potassium occur in intra-cellular fluids; with sodium they function in muscle metabolism.

Chlorine, which comprises about 65 per cent. of the acidic ions of the blood, is stored in the skin and also subcutaneously. Chlorides are of importance as hydrochloric acid in the gastric juice and occur in adequate amounts in most vegetable and animal foods with the exception of the cereal grains and their products.

Although poultry and pigs show low tolerance to sodium chloride (salt) their diets, which consist largely of cereal grains or their by-products, may occasionally require to be supplemented.

Because of the amounts of sodium and chlorine in milk dairy cows may require an additional supply. These supple-

ments may be given as mixtures incorporated with the food or as " licks."

Magnesium is present in all herbage and is widely distributed in the animal body; it is present mainly in the skeleton with smaller amounts in blood plasma. It is concerned in the formation of bones and teeth; it activates the enzyme phosphatase and functions in carbohydrate metabolism. Magnesium is related metabolically to calcium and phosphorus and deficiency may result in a disturbance of calcium metabolism. Lactation or grass tetany in cows and sheep follows a rapid fall in blood magnesium. Symptoms resemble those of milk fever and treatment is similar, i.e., by injection of calcium and magnesium chlorides, magnesium sulphate or calcium gluconate.

Iron, Copper and Cobalt occur in the body in very small amounts; the iron content is about 0·005 per cent. while copper and cobalt are present in traces. Iron is a constituent of the haemoglobin of the red corpuscles which are concerned with oxygen transportation; it also catalyses cellular oxidation processes. Copper, though not a constituent of haemoglobin, is concerned in its formation; it occurs in blood and liver. It functions as a catalyst in cellular oxidation-reduction reactions and occurs as copper-protein compounds, e.g., haemocuprein in the blood and hepatocuprein in the liver of mammals.

Deficiencies of iron or copper result in a lowered haemoglobin content of the blood, a condition known as nutritional anaemia. Though this may arise at any time it is most common during the suckling period. The iron and copper contents of milk are low and young animals have to depend on the reserves laid down in their bodies before birth. Colostrum contains approximately 17 times as much iron as normal milk and thus represents an invaluable supply to the calf. The livers of calves at birth contain more copper than do those of adult animals, a supply probably sufficient for the young animal until weaning. Iron deficiency in young pigs may be cured by giving them access to turves, by dosing with ferrous (iron) and copper sulphates or by painting the sow's udder with a syrup containing these salts in solution. Mud, with which the sow's udder occasionally

becomes covered, is alone often sufficient to prevent the onset of anaemia.

Copper deficiency in Great Britain results in a condition in sheep known as " swayback," which may prove fatal.

Cobalt deficiency causes " pining " in sheep, and " bush sickness " or " Pines " in New Zealand and Australia, probably by interfering with iron metabolism. The animals suffer from anaemia and become markedly emaciated, but small amounts of cobalt salts are effective as preventives or curatives. They may be administered orally as in licks or the amount in the herbage increased by dressing the pastures with 2 lb. cobalt sulphate (or chloride) per acre.

While some plants are relatively poor in iron, pulse crops, cereals and especially milling offals, and greens are satisfactory sources.

Iodine—The amount present in the body is small. It occurs mainly as thyroxine, a hormone secreted by the thyroid gland. Thyroxine controls the basal metabolism of the body and a deficiency results in retarded physical, mental and sexual development. When iodine is deficient enlargement of the thyroid gland takes place, i.e., a simple goitre results.

The young of iodine-deficient animals are either born dead or in a weak condition; iodine deficiency causes " hairlessness " in pigs. Goitre is not entirely the result of iodine deficiency but may be caused by a factor or factors which inhibit iodine metabolism. Although iodine is present in small amounts in all green foods, certain crops, namely, cabbage and kale, are goitrogenic, i.e., they tend to cause goitre when fed in excessive amounts.

Manganese—In the animal body manganese is present in practically all tissues and is stored mainly in the liver and kidneys. It functions in connection with reproduction, lactation and growth and is probably involved in tissue respiration. Manganese is associated with choline and biotin in the prevention of perosis in poultry.

Zinc—Zinc is widely distributed in small amounts in animal tissues and milk contains about 3 mg. per litre with rather more present in colostrum. While it is a dietary necessity for rats, its absence causing retarded growth and poor fur development, no deficiency has been recorded

amongst farm animals. It is probably concerned in carbohydrate metabolism.

Sulphur—Sulphur is chiefly present as a constituent of the amino acids cystine and methionine although it occurs as sulphate in the blood and in the hormone insulin.

Molybdenum—This trace element is present in relatively large amounts in certain Somerset pastures where it causes "teart," a condition manifest by severe scouring. Dairy cattle in particular lose condition rapidly. The administration of copper sulphate (1–2 g./day) cures the condition. Molybdenum toxicity is associated with calcareous soils and lime and manures containing lime increase the molybdenum absorbed, while the reverse is true of acidic fertilisers.

VITAMINS

These are chemical substances required in small quantities by all classes of animals. They are essential for growth, health and reproduction. Certain animals are able to synthesise some, but not all, and the remainder must be supplied in the food. Vitamins are classified according to their preferential solubility in fat or water, thus vitamins A, D, E and K are fat soluble, and B and C are water soluble.

Vitamin A is a growth and health factor found in fish liver oils where it accompanies vitamin D. It is also present in the livers of farm animals. Good sources of the vitamin are egg yolk, milk and colostrum and butterfat. It is not present in plants as such but green foods like kale and pasture grass contain a pigment or colouring matter known as carotene which can be converted into vitamin A in the livers of animals. Not all the carotene undergoes conversion for part passes unchanged into the milk of lactating cows. The extent to which carotene is converted into vitamin A depends on the breed of cow. Channel Island breeds in this respect are less efficient than others and in consequence their milk is deeper in colour.

Deficiency of vitamin A in the young animal leads to a cessation of growth. In adult animals it increases susceptibility to bacterial infections of the respiratory, alimentary and genito-urinary systems. Where deficiency is acute, xerophthalmia, an inflammatory condition of the eyes, may

develop. Vitamin A and the carotenes are susceptible to heat and oxidation and must therefore be stored away from air, heat and light. For these reasons losses in hay-making are considerable. The artificial drying of grass reduces these losses by the rapidity of the process, compactness of baling with exclusion of air, and subsequent storage under cover. Well made silage contains adequate supplies of carotene but root crops, except carrots, are poor. Since vitamin A is stored in the liver, deficiencies do not develop immediately but only after prolonged inadequacy in the diet.

Vitamin B_1, known as thiamine or aneurin, occurs in the seed coats of cereal grains and is thus present in milling offals. It is present also in brewers' yeast, the germ of cereals, plant leaves and in such animal products as egg yolk, liver, heart and kidneys. It can be synthesised in the rumen.

A deficiency of this vitamin causes diseases which affect the central nervous system, e.g., beri-beri in man and avian polyneuritis. These diseases are characterised by retarded growth and nervous disorders and, in extreme cases, paralysis and death. It is also believed to function in connection with carbohydrate metabolism.

Its wide distribution in animal foods combined with the ability of ruminants to synthesise it indicates that general shortages of B_1 are unlikely to occur although deficiencies may arise in the cases of non-ruminants and young animals.

Vitamin B_2 is known as riboflavin or lactoflavin. It occurs in such animal products as milk, whey, egg white, liver, heart and brain, and in green leafy forage crops. Cereals and cereal grains are poor sources of this vitamin which can also be synthesised in the rumen.

Riboflavin is a growth-promoting factor and is a constituent as a co-enzyme in a number of enzyme systems in which it is concerned with oxidation mechanisms in the body.

Although not required by ruminants it is necessary for other classes of animals including poultry. Its absence results in retarded growth, paralysis and death but adequate amounts are usually present in the food of farm animals.

Other members of the B_2 complex include:—

Pyridoxine, or adermin, which occurs in yeast, cereal grains and especially in grain by-products, vegetable fats, liver and milk. Pyridoxine is concerned in the formation of haemoglobin and in the metabolism of amino-acids. While no known deficiency has occurred in cattle and sheep its absence causes dermatitis in rats, a reduced growth rate in pigs and nervous degeneration in chicks.

Nicotinic acid, or niacin, is known as the " pellagra prevention " factor. It is widely distributed in plants and animals, e.g., in liver, yeast, wheat germ and bran. It can be synthesised by ruminants but for pigs it is a dietary necessity. Avitaminosis results in " black tongue " in dogs and pellagra in man, the latter disease being characterised by dermatitis, intestinal disturbances, nervous disorders and insanity.

Pantothenic Acid, which is called the chick anti-dermatitis factor, is widely distributed in foods of plant and animal origin such as liver, rice bran, molasses, wheat bran and yeast, and avitaminosis is unlikely to occur. It can be synthesised by cattle and sheep but is essential in the diet of dogs, pigs, turkeys and probably horses.

Choline is associated with manganese deficiency as a cause of perosis or slipped tendon in chicks.

Inositol is necessary for normal growth in chicks and for hair growth in mice and rats.

Folic acid promotes growth and prevents anaemia in chicks.

Biotin, sometimes known as vitamin H, is a growth factor for certain bacteria, yeasts and moulds. It is found in animal and vegetable products and may be synthesised in the rumen.

Vitamin B_{12} has been isolated from purified liver extracts. It is the anti-pernicious anaemia factor and contains cobalt as part of its molecule.

Vitamin C, or ascorbic acid, is widely distributed in fresh fruits and in leafy and other vegetables. While it is absent from resting tissues it is present in germinating seeds, i.e., where metabolism is going on.

It is present in such animal products as muscles, glandular tissues and milk but in general they are poor sources.

Vitamin C readily undergoes reversible oxidation and functions in oxidation-reduction processes in the body cells. Hay-making reduces the vitamin C potency of the original material and in milk pasteurisation and processing losses of 20 to 60 per cent., respectively, may occur.

Slight shortages of ascorbic acid result in minor oral ailments; serious deficiencies cause scurvy. Certain species, e.g., rats, dogs and birds can synthesise this vitamin. Farm animals, with the exception of pigs, seem unlikely to suffer from deficiencies and dietary need is otherwise restricted to guinea pigs, monkeys and man.

The Vitamins D include D_2 or calciferol and D_3. They are present with vitamin A in natural oils and fats. They are of limited distribution; plants are devoid of the vitamins and animals have little capacity for storing them. Fish liver oils, egg yolk and butter fat are good sources.

Vitamins D_2 and D_3 are produced by the irradiation of certain sterols with ultra-violet light. In the case of farm animals ergosterol, present in the skin, is converted by sunlight into calciferol, the name of which is derived from its association with calcium and phosphorus metabolism.

An absence of vitamin D results in imperfect calcification of bones and teeth even in the presence of calcium and phosphorus in the correct proportion and in adequate amounts. Rickets in the young animal or osteomalacia in the adult may be cured by sunlight and the activation of ergosterol or by the addition of cod liver oil to the food. Hence vitamin D is known as the anti-rachitic vitamin. Exposure of the food to sunlight may also be sufficient to produce an adequate supply of the vitamin.

The vitamin D potency of milk is variable and it contains approximately ten times as much in summer as in winter though at no time does it contain sufficient to prevent rickets. Hence the importance of sunlight and/or cod liver oil to the young animal.

While it is practically absent from growing plants, the drying of crops in sunlight, as in hay-making, causes the development of small amounts. The feeding of cacao-shell meal, which is a useful source of vitamin D, supplements the vitamin D potency of the ration of stall-fed dairy cows.

Care must be taken to avoid feeding excessive amounts of cacao-shells since fermentation produces a toxic principle, theobromine.

Vitamin E is associated with reproduction and its deficiency causes sterility in both sexes of certain animals. The provision of vitamin E will not cure forms of sterility resulting from other causes, e.g., deficiencies of other vitamins or inorganic elements.

It is widely distributed in farm foods and green plants such as spinach and lettuce contain satisfactory amounts. The oils of seed embryos, e.g., maize and wheat germ oils, are especially good sources. It is also present in animal products although milk contains very little. Its widespread distribution is probably sufficient to ensure adequate supplies in the rations of farm animals.

Vitamin K is widely distributed in animal foods particularly in green plants and is also present in egg yolk and liver.

It is concerned with the formation of prothrombin in the liver and its absence from mammalian diet leads to a failure of the blood clotting mechanism due to a lowered blood content of prothrombin.

DIGESTION

The purpose of digestion is to produce simple molecules capable of passing through the membranes of the digestive tract from the complex food substances ingested by the animal. This result is achieved by chemical action, assisted by mechanical processes. The mechanical processes of chewing and mastication by the teeth are followed by rhythmic muscular movements of stomach and intestines whereby the food is broken up, thoroughly mixed with digestive juices and exposed to the enzymes concerned with the chemical changes.

In non-ruminants the food is wetted and mixed in the mouth with the saliva, an alkaline secretion which, in certain though not all species, contains an enzyme capable of hydrolysing starch. After swallowing, the food is passed through the oesophagus into the stomach. There it is gradually mixed with the gastric juice. Due to the presence of hydrochloric acid in this fluid the alkalinity of the food

mass is reduced, the action of the salivary enzyme is inhibited and a proteolytic enzyme begins to function. From the stomach the food passes into the small intestine, consisting of duodenum, jejunum and ileum, which receives alkaline pancreatic juice, bile, from the liver, and alkaline intestinal juice. In the pancreatic juice are enzymes which break down proteins, fats and starch; the bile in addition to its content of waste products also contains salts which assist in the emulsification of fats, and in the intestinal juice are enzymes which complete the breaking down of protein and sugars.

Simple compounds are absorbed mainly through the walls of the small intestine which are lined with cone-like projections called " villi." Digestion is however continued in the large intestine and undigested residues are voided as faeces.

In ruminant animals such as cattle and sheep, the food when swallowed passes into the rumen or reticulum in which it is subjected to muscular movements. In these compartments of the compound " stomach " the food is softened to a fine consistency and fermented. This is assisted by regurgitation and remastication, and by further kneading in the omasum. The food then passes into the true stomach or abomasum.

Thereafter digestion is similar to that in non-ruminants. The rumen, reticulum and omasum acting as storage organs enable ruminant animals to deal with vast quantities of fibrous foods. The horse, a non-ruminant, possesses a large caecum or colon which provides it with the ability to utilise relatively large quantities of bulky fodders; pigs can deal only with limited amounts.

DIGESTION OF CARBOHYDRATES

The carbohydrates are broken down into simple sugars by the hydrolytic action of specific enzymes secreted into the digestive tract. Since starch is the predominant carbohydrate in plant tissues glucose is the chief end product of carbohydrate digestion. The enzyme ptyalin present in small amounts in the mouths of most farm animals, and in larger amounts in the pig, converts starch into dextrins and then maltose. In the small intestine starch which has escaped

salivary digestion is converted into maltose by amylase. Here also the enzyme sucrase converts sucrose into glucose and fructose, maltase converts maltose into glucose and lactase hydrolyses lactose into glucose and galactose.

DIGESTION OF CRUDE FIBRE

This is brought about by enzymes secreted by symbiotic micro-organisms in the digestive tracts of animals. The rumen of ruminant animals and the caecum and colon of the horse are the principal centres of this activity by which cellulose and pentosans are converted into gases, e.g., carbon dioxide and methane, organic acids such as acetic and lactic, and simple sugars.

By this method ruminants can digest about 50 per cent. of the crude fibre of most foods.

The digestibility of the complex polysaccharides decreases with the age of the plant, hence the " crude fibre " of fresh or dried pasture grass is more easily digested than that of hay. Digestibility of crude fibre is also lowered by the presence of lignin, which is itself indigestible.

DIGESTION OF FAT

The acidity of the stomach, due to the presence of hydrochloric acid, helps to release fatty constituents of food from their coverings and slight fat hydrolysis may be brought about by the warm hydrochloric acid and by a gastric lipase. In the small intestine fats are hydrolysed into fatty acids and glycerol by the lipase steapsin. This process is facilitated by the presence of alkaline bile salts which saponify and emulsify the fat and thus bring the globules into intimate contact with the enzyme.

Certain other lipides, known as phospholipides, contain a phosphoric acid group and a nitrogenous base. Their importance depends upon the fact that they are fat soluble and have an affinity for water. They are thought therefore to be at least partly responsible for the transportation of fat.

DIGESTION OF PROTEINS

In the stomach protein is partly hydrolysed to proteoses and peptones by the proteolytic enzyme pepsin which functions most efficiently at pH 2·0. On entering the small intestine the pancreatic juice, pH 8, containing the enzyme

trypsin, further hydrolyses protein to proteoses or polypeptides. The intestinal juice, which is an alkaline fluid of pH 7·7, contains a number of enzymes collectively known as peptidases, and formerly thought to be a single enzyme erepsin, which complete the digestion of protein by hydrolysing polypeptides to amino acids.

Nucleoprotein first undergoes gastric digestion with the formation of protein and nuclein while the latter product undergoes tryptic digestion to form protein and nucleic acids. Nucleic acids are fermented by a number of enzymes present in the intestinal juice with the eventual production of hexose and pentose sugars, phosphoric acid and purine and pyrimidine bases.

METABOLISM

This involves two types of changes, Anabolism, the building up of complex molecules from simple ones, and Catabolism, the breaking down of complex into less complex molecules. Catabolic changes which are often oxidative in character involve the utilisation of oxygen transported by the blood to the tissues from the lungs.

Carbohydrates—The simple sugars, hexoses, which form the end point of carbohydrate digestion, pass through the intestinal wall into the blood. In the liver they are built up into glycogen which there forms a reserve of energy. The subsequent utilisation of glycogen involves its conversion into glucose.

When adequate reserves of carbohydrate are present in the liver the surplus blood glucose may be utilised as follows:

(*a*) Converted into glycogen in muscle cells to provide for the energy expended in muscular work.

(*b*) Oxidised in body cells to provide heat for the maintenance of body temperature.

(*c*) In the synthesis of lactose in the mammary gland.

(*d*) Converted into body fat and stored as adipose tissue around the viscera and in the so-called fat depots.

Fat—From the small intestine the smaller fat particles or chylomicrons ($< 0{\cdot}5\ \mu$) may be absorbed directly through the gut into the lacteals.

Absorption of the products of fat digestion involves the release of the fatty acids from water-soluble complexes

with the bile salts and their combination with glycerol to form fat while passing through the absorbing cells.

After absorption the fat may be utilised catabolically to provide energy, as heat for the maintenance of body temperature, and for the performance of muscular activities.

Anabolically it may be converted into milk fat whilst surplus amounts are stored in the adipose tissues together with fat produced from ingested carbohydrates.

Approximately one half of the adipose tissue is found subcutaneously, the remainder being present around certain organs such as the kidneys and in the muscles.

The end points of fat catabolism are carbon dioxide and water which are excreted via the lungs, kidneys and skin.

The main function of fats and oils is the provision of energy. Since they contain less oxygen in their molecules than either carbohydrates or protein they require very much more oxygen to bring about complete oxidation and therefore supply more energy. Fat yields, weight for weight, about 2·3 times more energy than carbohydrate.

While animals have the ability to synthesise fats from carbohydrates a dietary deficiency of fat lowers the digestibility of the ration. A minimum fat intake is essential for health and growth but excessive amounts are incompletely digested and the fatty acids produced act as irritants.

Certain oils, e.g., halibut liver and cod liver oils, are also of importance since they contain vitamins A and D which are also present in butter fat.

Protein—The amino acids resulting from protein metabolism are absorbed and transported by the blood to the tissues where they may be re-synthesised to restore tissue waste, to build up body protein during growth or for the formation of the protein of a body product such as milk or wool. Glandular secretions such as hormones require amino acids for their formation. Amino acids unsuitable for use synthetically or in excess of the body's requirement are de-aminised, i.e., nitrogen is removed as ammonia, and the non-nitrogenous residue is oxidised and used as a source of energy. The ammonia is excreted as urea in the urine. The pentose and hexose sugars, resulting from the digestion of nucleoprotein, enter into carbohydrate metabolism.

The main function of the proteins is to provide the means whereby body tissues, body coverings and body products may be built up and the ability of a food to meet these requirements depends qualitatively and quantitatively upon the nature and types of its amino acid constituents. The ability of an animal to synthesise amino acids for protein building is limited, hence the lack of particular amino acids which the animal needs but is unable to synthesise restricts the utilisation of food protein.

Indispensable amino acids—Amino acids which cannot be synthesised or which cannot be synthesised sufficiently rapidly to meet the needs of the animal must be present as constituents of food protein and are known as essential or indispensable amino acids. They include lysine, tryptophane, histidine, arginine, valine, leucine, isoleucine, threonine, methionine and phenylanine, which are essential for growth.

Certain amino acids, although normally regarded as non-essential, may in certain conditions become essential, e.g., when another amino acid is either present in small amounts or completely absent from the diet.

Proteins which contain all the indispensable amino acids have high biological values. These include all the animal proteins, with the exception of gelatin, and a number of plant proteins. Most plant proteins are incomplete, i.e., they are deficient in one or more of the essential amino acids. It is therefore important that animals on strictly herbivorous diets should receive protein from a variety of sources. It is known that the feeding of animal proteins, e.g., skimmed milk, increases the value of cereal proteins when they are fed together.

The efficiency or biological value of a protein is its capacity to meet the requirements of the tissues; it may be expressed thus:—

$$\text{Biological value} = \frac{\text{Nitrogen used anabolically} \times 100}{\text{Nitrogen absorbed}} \text{ per cent.}$$

True Protein and Crude Protein—In addition to proteins animals and their food contain simpler nitrogenous substances such as peptides, amino acids, ammonium salts, nitrates, etc., collectively referred to as "amides." The crude protein of feeding stuffs which is found by determining

the total nitrogen content and multiplying by 6·25*, thus includes non-protein nitrogen. According to the concept of true protein this non-protein or "amide" nitrogen is regarded as making no contribution to protein nutrition, yet amino acids and peptides are equally as valuable as though actually part of the protein molecule. It is known, furthermore, that amide, nitrate and ammoniacal nitrogen may contribute to the protein nutrition of ruminants by bacterial synthesis in the rumen.

The distinction between crude and true protein has lost much of its significance by a recognition of the fact that the value of protein depends upon its "quality," i.e., upon the kinds and amounts of amino acids present in it. Thus true protein has not the definite nutritive value which it was formerly thought to possess. The value of the "amide" fraction has long been recognised in the United States of America and hence crude protein is taken as the true measure of the value of a food in protein nutrition. Owing to the high solubility of the "amide" fraction and its consequent rapid passage through the alimentary tract it may not be, however, so efficient as protein nitrogen. In Great Britain its effectiveness as protein is assessed at 50 per cent., hence the protein value of a food may be expressed by the protein equivalent (P.E.) which is the mean of the digestible crude and the digestible true protein.

CHEMICAL COMPOSITION OF FOODS

THE CONCENTRATED FOODS

The concentrated foods include foods of animal and vegetable origin and are conveniently subdivided into carbohydrate- and protein-rich foods.

Carbohydrate concentrates include the cereal grains. They generally have protein equivalents of less than 10 but are correspondingly high in starch equivalent. These foods show wide variation in respect of oil, which ranges from 1·5 per cent. in barley to 4·8 per cent. in wheat. The protein content is less variable and is least in rice (8·3 per cent.) and greatest

* While individual proteins vary in their nitrogen content it is usual to adopt a standard of 16 per cent. Hence protein can be calculated by multiplying Total N. by $\frac{100}{16}$, i.e., $N \times 6{\cdot}25$.

in wheat (12·1 per cent.). The crude fibre is also variable because of the presence of husks in oats and barley and their absence from wheat and maize. In barley the husk forms about 10 per cent. of the grain and in oats about 25 per cent. The percentages of crude fibre in the grain range from 1·9 in wheat and rye to 10·3 in oats. The cereals are deficient and badly balanced in mineral matter but phosphate and potash are generally satisfactory. Lime and chlorine are invariably low; in conjunction with the deficiency of protein these are serious factors in intensive milk production. Such foods have a rachitogenic effect, the result of their low lime content and of the presence of phytic acid which decreases the absorption of lime in these and other foods from the gut. They are a good source of vitamins B and E.

Carbohydrate-rich foods are used for fattening and to widen the nutritive ratio of diets rich in protein.

The protein concentrates consist of foods of animal origin such as dairy and slaughterhouse by-products, e.g., whey, dried blood and meat meal, fish residues, and foods of vegetable origin such as peas, beans, brewery and distillery by-products and cakes and meals from the oil-milling industry.

Protein-rich foods such as carcase residues are prepared in conformity with the Foot and Mouth (Boiling of Foodstuffs) Order, 1932, which, with certain exceptions, involves heating to at least 100° C. for a minimum period of 1 hour. The moisture and fat are removed by heating or the fat may be extracted by a solvent. The residues when dried are freed from the solvent and ground.

Dried blood contains about 80 per cent. protein but is low in mineral matter.

Meat meals vary in composition but may contain from 40–70 per cent. protein and, depending on the efficiency of extraction, 2–17 per cent. fat. Meat and bone meal, which contains ground bones in addition to ground meat meal, contains about 50 per cent. protein and 10 per cent. each of lime and phosphoric acid. Sterilised steamed bone flour, prepared from bones from which fat and gelatin have been removed, contains about 46 per cent. lime and 31 per cent. phosphoric acid. Fish meals vary in quality for feeding purposes. White fish meal made from heads, bones and adhering flesh of white fish contains not more than 6 per cent. oil and 4 per cent. salt. Fish meal made from damaged,

oily fish contains 10–15 per cent. oil. The residual oil in the latter renders it unsuitable for animal feeding. These foods are all rich in high quality protein and certain of them are rich in lime and phosphoric acid.

The dairy by-products are residues from the manufacture of butter, cheese and other milk products or from the separation of cream. They may be fed in liquid form, containing about 90 per cent. water, or dried. Dried skimmed milk and separated milk are rich in highly digestible protein and mineral matter and contain most of the protein, lactose and ash of the original milk; dried buttermilk, which may contain salt, contains rather more protein and less lactose than dried separated milk the approximate composition of which is 30 per cent. protein, 47 per cent. lactose and 8 per cent. mineral matter. Dried whey contains about 70 per cent. lactose, 8 per cent. mineral matter, 1·5 per cent. fat and only 12 per cent. protein, since cheese-making involves the removal of the greater part of the protein, and some of the fat, from the milk.

The protein concentrates of vegetable origin include such home-grown foods as peas and beans, by-product foods such as brewers' and distillers' grains and dried yeast, and oil cakes. They usually contain not more than 15 per cent. water. Peas and beans are rich in protein (18–20 per cent.) and carbohydrate (52–44 per cent.) but contain only about 1 per cent. of ether extract. Their ash content, 3 per cent., is low and resembles that of the cereal grains since it is poor in lime and chloride but comparatively rich in phosphoric acid and potash. Dried brewers' and distillers' grains contain 12·5–19·5 per cent. protein equivalent and have nutritive ratios of 1 : 3 or 1 : 4. They are therefore approximately balanced for milk production. Cereal milling offals are characterised by the presence of larger amounts of fibre, oil, protein and ash than either the flour or the original grain. In addition they are richer in vitamin B and, since the germ is included with the offals, they are a good source of vitamin E.

The oil cakes and meals are prepared from the residues of oleaginous seeds containing 17–50 per cent. oil, from which the oil has been extracted for soap and margarine making by hydraulic pressure, the expeller process or by solvent extraction.

Hydraulic pressure residues contain 5–10 per cent. oil, residues from the expeller process contain 4–8 per cent. and the solvent extracted meals contain only 1–2 per cent oil. The latter process involves steam heating of the residues to remove the last traces of solvent. These cakes and meals are rich in protein but the amounts of oil vary with the extraction process and the crude fibre content varies with the degree of decortication.

In feeding practice fibrous foods must accompany protein concentrates to add bulk to the ration and to achieve the correct nutritive ratio.

BULKY FOODS

Roughages or Coarse Fodders—These foods are characterised by a high fibre and low protein content and include hay, straw and chaff. The chemical composition of the standing crop for hay depends upon a number of factors not the least of which is the botanical composition of the sward. This factor is influenced by fertiliser and grazing practices, the relative proportions of inferior species such as Yorkshire fog and bent to rye-grass and timothy and by the amounts of clover and legumes present. The latter increases the amounts of protein and lime in the hay. The nutritive value of hay depends upon the stage of growth at which it is cut, the crude fibre increasing in amount and decreasing in digestibility as, with maturity, it becomes lignified. At the same time a transfer of nutrients such as protein from the vegetative parts to the seeds takes place. If hay be made later the seeds will be shed; if present they may be resistant to digestion and valuable food material lost. If the crop be exposed to rain during hay-making considerable losses by leaching of mineral matter, protein and soluble carbohydrates take place. The chief mineral constituents affected are phosphoric acid, chloride and potash, the loss of lime being relatively small. The consequence is a reduction in palatability and feeding value.

Harvesting involves losses, estimated at about 10 per cent., due to cellular respiration and the oxidation of carbohydrates to carbon dioxide and water for some time after cutting. Mechanical operations result in damage to the brittle dry leaf and cause losses estimated at from 5–10 per cent. while

a similar loss in the stack may be attributed to fermentation by enzymes and bacterial action in addition to respiration losses when the hay has been imperfectly dried.

These losses do not affect the crude fibre and hence a high crude fibre content is further emphasised and decreases the digestibility of the hay. Similarly heating in the stack reduces digestibility.

The dry matter content of hay is of the order of 85 per cent., crude protein content varies from 7·5–13·5 per cent., and crude fibre from 33·5–19·3 per cent. for poor and good meadow hay respectively. The starch equivalent varies from 20–40 per cent. and the protein equivalent from 3–12 per cent. The mineral matter (5–8 per cent.) may be regarded as a good source of lime and phosphoric acid but the former may vary from 0·3–2·3 per cent. and the latter from 0·3–0·8 per cent. Hay made from leguminous swards is less variable in composition than meadow hay and average seeds hay contains 12 per cent. crude protein, 2·8 per cent. oil and 27 per cent. crude fibre with 1·5–2 per cent. lime.

The pro-vitamin A potency of grass is much reduced by hay-making, losses of carotene having been estimated at 50–60 per cent. depending upon conditions.

The growth of cereal crops to maturity to produce seed involves an almost complete transfer of nutrients from leaves and stem to the seed. Hence the straws are low in protein and high in fibre content and contain about 86 per cent. dry matter. Starch equivalents vary between 13 and 23 and protein equivalents between 0·1 and 0·7 the lowest values being for wheat straw. Since oats are cut before being completely ripe the straw is less lignified and has a higher nutritive value than other straws. Barley straw is of low feeding value; its ash is poor in lime and phosphoric acid and contains much silica. The nutritive values of the straws can be improved by treatment with caustic soda and afterwards washing them free from alkali; the process is known as "pulping."

THE SUCCULENT FOODS

Roots and Green Foods—This group of foods is characterised by the presence of 79–90 per cent. water and includes forage crops, e.g., lucerne, clovers, graminaceous

crops, e.g., rye grasses and cereals, green crops, e.g., kale and rape, and roots and tubers, e.g., mangolds, swedes and potatoes.

Characteristics of these foods are the high percentage of carbohydrate (up to 20 per cent.) and the low content of protein (2 per cent.) and oil (1 per cent.). The roots have dry matter contents ranging from 8·5 per cent. in turnips to 10–14 per cent. in swedes; potatoes have 22–24 per cent. dry matter. The dry matter of roots and tubers resembles that of the cereals since it is rich in carbohydrate and poor in protein, oil and ash. The type of carbohydrate differs, however; in potatoes it is largely starch and in roots a mixture of glucose and sucrose. In mangolds part of the carbohydrate present as sucrose undergoes inversion to glucose and fructose during the storage period without affecting the nutritive value of the roots. Although swedes have the highest nutritive value of all root crops they are exceeded in value by potatoes and barley since for ruminants sucrose has only 75 per cent. of the productive value of starch. In mangolds much of the nitrogen is in "amide" form and storage prior to feeding enables nitrate-nitrogen to be converted into amides.

Kales have a high mineral content particularly of lime, 1·6–2·6 per cent., chloride and potash and hence tend to make good the lack of lime in cereal grains and hay. In addition they contain satisfactory amounts of iron, magnesium and phosphoric acid. They are also useful sources of protein, vitamin C and carotene.

Sugar beet pulp contains about 85 per cent. water and may be fed in this condition or dried, the dried pulp being slightly inferior to oats in feeding value.

The comparative richness in protein of the green fodders makes them the natural supplement for carbohydrate-rich foods.

GRASSLAND HERBAGE

Grassland herbage contains about 20 per cent. dry matter the amount and composition of which varies with the stage of maturity. The chemical composition of grassland is largely influenced by management which results in changes in botanical composition and hence in nutritive value.

Composition and digestibility may also be affected by climate, e.g., low temperatures decrease the growth rate and this is accompanied by increased lignification and decreased digestibility and feeding value even though the grasses are still in the leafy stage.

A marked increase in the percentages of crude fibre occurs with increasing maturity. In young plants cellulose forms a large proportion of the crude fibre; at this stage the cellulose cell walls are easily disrupted and their contents subjected to bacterial fermentation so that 75–80 per cent. of the crude fibre is digestible. As the plant matures the ratio of stem to leaf increases, cell walls become lignified and resistant with the result that the crude fibre is less digestible. In addition the mineral and vitamin contents of the grasses decrease with advanced stage of growth.

Controlled, intensive grazing results in grass of the character of a protein concentrate with amounts of protein, on a dry matter basis, approaching or equalling that of linseed cake and being of high biological value.

Pasture Herbage	C.P. per cent.	C.P. in D.M. per cent.
Close grazed, 3-weekly intervals	4·5	22·5
Close grazed, 4-weekly intervals	3·5	17·5

The grass is also rich in ash (9 per cent. on dry matter), particularly in lime, phosphoric acid and potash, and in carotene.

Dried Grass—Grass produced under conditions of good management and cut and dried at the correct stage has the character of a protein concentrate. It is also a valuable source of minerals and of carotene. Substantial losses of carotene may occur during drying and subsequent storage. Because of variability in composition dried grass is classified as follows:

Grade	Percentage of Crude Protein in Dry Matter
1	>17
2	14–17
3	12–14
Super hay	8–12

Silage—Ensilage is the process whereby green herbage or other suitable crops are compressed in stacks, pits, clamps or tower silos in order to control the air supply and hence the type of fermentation.

On the material ensiled and conditions under which it is made will depend the type and quality of the silage produced. The crop must be sufficiently compacted to restrict respiration of living cells and so reduce the loss of carbohydrates. An adequate supply of air must nevertheless be available for aerobic organisms to convert carbohydrates into acetic, propionic and lactic acids. The development of acidity prevents undesirable fermentation and the importance of lactic acid in this respect gave rise to the practice of adding molasses as a carbohydrate source to protein-rich crops when ensiled.

Other modifications of the process involve the use of mineral acids or acid-producing substances to attain a pH of 3–4. With this degree of acidity bacterial fermentation by which butyric acid is produced and proteolysis by enzymes are greatly depressed.

Well preserved silage is light brown in colour; it possesses a slight vinegary odour and the pH is usually 4·0–4·5. When the material ensiled is stemmy and difficult to compress overheating, due to excessive respiration, may occur. Overheated samples are dark brown in colour, with a distinct " caramel " smell and the pH is much the same as for well made silage.

In colour, underheated silage is light green and has a foul smell due to the putrefactive changes that occur when fermentation is of the butyric acid type. This occurs when succulent or wet herbage is ensiled and is due to over-compression and underheating. The pH of silage of this type is usually over 5.

In composition and digestibility well made silage does not differ much from that of the fresh crop. Certain losses of nutrients may occur during the process of ensilage but there is appreciable conservation of the carotene. Well made silage contains between 250 and 500 mg./Kg. of carotene. This compares favourably with fresh grass, 300–600 mg./Kg. and dried grass, 250–500 mg./Kg. and is immensely superior to hay which may contain less than 40 mg./Kg.

NUTRITIVE VALUES OF FOODS

DIGESTIBILITY

The digestibility of foods is determined by experiments with cattle or sheep during which the amount of food fed and faeces voided per day and per experimental period are noted. Representative samples of foods and faeces are taken daily for analysis and allowance is made for unconsumed food. Analysis of foods and faeces gives information on the total dry matter consumed and voided and of the relative extent to which other constituents, e.g., protein, have been digested.

Results, expressed as percentages of the amount of total dry matter or nutrient consumed, are known as digestibility coefficients. The assumption thereby made is that faecal residues are indigestible; in fact, for a number of reasons this is not strictly true. The percentages of digestible nutrients are then calculated, using the digestibility coefficients, from the total percentages of nutrients given by analysis.

The digestibility of crude protein can be estimated by the digestion of the food protein " in vitro " using a solution of pepsin in dilute hydrochloric acid. Results are of limited use and vary with the fineness with which the food is ground.

The digestibility of foods also varies " in vivo " and in general is mainly affected by the crude fibre content. A high percentage of crude fibre is associated with maturity in grassland products; its resistance to the digestive juices protects the constituents of the cells from digestion and thus decreases the digestibility of the food as a whole. There appear to be but slight differences in the relative capabilities of young and old animals to digest foods, and while gentle exercise stimulates digestion hard work may impair it.

The effect of grinding on the digestibility of coarse foods is probably negligible but the process reduces the mechanical operations of the animal in mastication and consequently enhances their feeding value. In the case of foods which tend to form a doughy mass in the stomach the presence of a proportion of fibrous food such as bran helps to open up the mass to the action of the digestive juices. Peas, beans, maize, linseed, barley, oats and wheat have a tendency to pass unaltered through the alimentary tract unless crushing or grinding has taken place.

TABLE 48: COMPOSITION AND NUTRITIVE VALUE

The data in this table are derived from Bulletin No. 48 of the Ministry of Agriculture, mission, from the "Feeding of Livestock" by Professor S. J. Watson (Nelson & Sons Ltd.,

FOOD	AVERAGE COMPOSITION PER CENT. AS SHOWN BY ANALYSIS					
				Carbohydrates		
	Dry Matter	Crude Protein	Ether Extract (Oil)	Nitrogen-free Extractives (Soluble)	Crude Fibre	Ash
(1)	(2)	(3)	(4)	(5)	(6)	(7)
I. CONCENTRATED FOODS						
(A) CARBOHYDRATE-RICH						
Barley	85·1	10·0	1·5	66·5	4·5	2·6
Maize	87·0	9·9	4·4	69·2	2·2	1·3
Oats	86·7	10·3	4·8	58·2	10·3	3·1
Rye	86·6	11·5	1·7	69·5	1·9	2·0
Wheat	86·6	12·1	1·9	69·0	1·9	1·7
(B) PROTEIN-RICH						
(i) ANIMAL PRODUCTS						
Blood meal	86·0	81·0	0·8	1·5	—	2·7
Meat meal, pure	89·2	72·2	13·2	—	—	3·8
Meat and bone meal	90·3	50·3	15·0	1·0	—	24·0
Feeding meat meal, high fat.. ..	90·5	60·0	11·0	0·5	—	19·0
Feeding meat meal, low fat	93·0	66·7	2·9	4·0	—	19·4
Fish meal, white	87·0	61·0	3·5	1·5	—	21·0
(ii) DAIRY BY-PRODUCTS						
Dried buttermilk	90·0	35·3	7·0	40·0	—	7·7
Dried skimmed milk	89·7	32·8	1·5	47·9	—	7·5
Dried whey	92·2	12·6	1·4	70·5	—	7·7
(iii) VEGETABLE ORIGIN						
Beans (bean meal)	85·7	25·4	1·5	48·5	7·1	3·2
Cottonseed cake or meal (decort.) ..	90·2	41·2	8·0	26·5	7·8	6·7
Cottonseed cake (undecort.) ..	87·9	23·2	5·0	32·6	21·3	5·8
Dried brewers' grains	89·7	18·3	6·4	45·9	15·2	3·9
Dried distillers' grains	92·0	27·7	11·6	40·8	10·1	1·8
Dried yeast	95·7	48·5	0·5	35·5	0·5	10·7

OF THE MORE COMMONLY USED FEEDING STUFFS

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1949) and from unpublished analyses made at Seale-Hayne Agricultural College.

MINERAL COMPOSITION PER CENT.				DIGESTIBLE NUTRIENTS PER CENT.					CALCULATED FROM DIGESTIBLE NUTRIENTS			
							Carbohydrates					
Lime (CaO)	Phosphoric Acid (P_2O_5)	Potash (K_2O)	Chlorine (Cl)	Crude Protein	True Protein	Oil	Soluble	Fibre	V Number	Protein Equivalent (P.E.)	Starch Equivalent (S.E.)	Ratio S.E. : P.E.
(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
0·07	0·84	0·57	0·12	7·6	7·0	1·2	60·9	2·5	98	7·3	71·4	9·8
0·02	0·82	0·40	0·07	7·9	7·4	2·7	63·7	0·08	100	7·7	77·6	10·0
0·14	0·81	0·55	0·07	8·0	7·2	4·0	44·8	2·6	95	7·6	59·5	7·8
0·07	0·95	0·60	0·02	9·6	8·7	1·1	63·9	1·0	95	9·2	71·6	7·8
0·05	0·86	0·60	0·08	10·2	9·0	1·2	63·5	0·9	95	9·6	71·6	7·5
0·05	0·22	0·31	0·85	72·7	63·6	0·8	—	—	100	68·2	62·9	0·9
0·40	0·70	0·10	0·27	67·2	63·6	12·5	—	—	100	65·4	91	1·4
10·50	9·30	0·80	1·40	39·2	29·2	14·3	—	—	100	34·2	67·8	2·0
8·00	7·20	0·70	1·20	56·4	42·4	9·8	0·5	—	100	49·4	72·3	1·5
8·42	7·35	0·72	1·23	58·6	43·4	2·4	3·9	—	100	51·0	59·6	1·2
10·00	9·00	1·20	1·00	55·0	51·0	3·3	1·2	—	100	53·0	58·9	1·1
1·52	2·30	1·89	1·02	—	—	—	—	—	—	—	—	—
1·41	1·88	1·88	0·94	—	—	—	—	—	—	—	—	—
0·92	1·25	1·73	1·08	—	—	—	—	—	—	—	—	—
0·18	0·88	1·28	0·03	20·1	19·3	1·2	44·1	4·1	96	19·7	65·8	3·3
0·35	2·80	1·80	0·03	35·4	33·9	7·5	17·7	2·2	97	34·7	68·4	2·0
0·30	2·50	1·60	0·05	17·8	16·8	4·6	17·7	4·5	84	17·3	41·6	2·4
0·40	1·60	0·20	0·06	13·0	12·1	5·6	27·6	7·3	84	12·6	48·3	3·8
0·40	0·68	0·20	0·06	19·6	18·7	10·2	25·3	4·8	84	19·2	57·2	3·0
0·33	6·10	2·22	0·03	41·6	39·9	0·2	29·2	—	100	40·8	67·2	1·6

FOOD (1)	AVERAGE COMPOSITION PER CENT. AS SHOWN BY ANALYSIS — Dry Matter (2)	Crude Protein (3)	Ether Extract (Oil) (4)	Carbohydrates — Nitrogen-free Extractives (Soluble) (5)	Carbohydrates — Crude Fibre (6)	Ash (7)
I. CONCENTRATED FOODS—continued						
Groundnut cake (decort.)	89·7	46·8	7·5	23·2	6·4	5·8
Groundnut cake (undecort.) ..	89·7	30·2	9·1	21·8	22·9	5·7
Linseed cake	88·8	29·5	9·5	35·5	9·1	5·2
Linseed or linseed meal	92·9	24·2	36·5	22·9	5·5	3·8
Malt culms	90·0	24·4	2·0	42·4	14·0	7·2
Maize gluten feed	89·6	23·5	3·4	56·7	3·5	2·5
Palm kernel cake or meal	89·0	19·2	6·0	46·5	13·4	3·9
Palm kernel meal (extracted) ..	90·0	19·0	2·0	49·0	10·0	4·0
Peas or pea meal	86·0	22·5	1·6	53·7	5·4	2·8
Soya bean cake	85·5	43·1	5·6	26·3	5·1	5·4
Soya bean meal (extracted)	88·7	44·7	1·5	31·9	5·1	5·5
(iv) WHEAT FEEDS						
Finest grade, fine middlings	86·7	17·0	4·[illegible]	60·8	2·3	2·4
Second grade (fine wheatfeed) ..	86·0	15·9	4·5	55·9	6·0	3·7
Fourth grade, bran	87·0	15·1	3·8	52·8	9·5	5·8
Broad bran	87·0	14·7	4·0	52·1	10·3	5·9
II. COARSE FODDERS						
(A) HAYS						
Lucerne, before flowering	85·0	16·4	2·4	31·5	27·3	7·4
Lucerne, full flower	85·0	14·5	2·7	29·7	30·0	8·[illegible]
Meadow, all leaf	85·0	13·5	3·0	41·4	19·3	7·[illegible]
Meadow, early flower	85·0	10·0	1·6	40·0	26·6	6·8
Meadow, flowering	85·0	7·6	1·5	40·8	28·7	6·4
Meadow, full flower	85·0	4·8	1·2	43·1	30·6	5·3
Oat and vetch	85·0	11·7	3·4	36·7	24·5	8·7
Sainfoin, before flowering	84·2	15·4	3·2	34·0	24·9	6·7
Seeds, high clover	85·0	12·2	1·3	42·2	22·1	7·2
Seeds, medium clover	85·0	9·1	1·2	43·2	25·2	6·3
Seeds, low clover	85·0	7·4	1·2	45·0	25·6	5·8

MINERAL COMPOSITION PER CENT.				DIGESTIBLE NUTRIENTS PER CENT.					CALCULATED FROM DIGESTIBLE NUTRIENTS			
							Carbohydrates					
Lime (CaO)	Phosphoric Acid (P_2O_5)	Potash (K_2O)	Chlorine (Cl)	Crude Protein	True Protein	Oil	Soluble	Fibre	V Number	Protein Equivalent (P.E.)	Starch Equivalent (S.E.)	Ratio S.E. : P.E.
(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
0·20	1·30	1·50	0·03	42·0	40·6	6·8	19·7	0·5	98	41·3	73·0	1·8
0·20	1·00	1·10	—	27·7	26·8	8·2	18·4	2·6	86	27·3	56·8	2·1
0·51	1·70	1·30	0·09	25·3	23·9	8·7	28·5	4·5	97	24·6	74·0	3·0
0·30	1·40	1·10	0·09	19·4	18·1	34·7	18·3	1·8	99	18·8	119·2	6·3
0·20	1·80	2·00	0·35	19·9	12·0	1·5	30·9	12·7	75	16·0	43·4	2·7
0·10	0·70	0·20	0·04	20·0	18·4	2·7	49·3	2·5	100	19·2	75·6	3·9
0·30	1·10	0·50	0·16	17·5	16·4	5·3	39·4	5·1	100	17·0	73·2	4·3
0·30	1·20	0·50	—	17·1	16·0	1·9	43·5	8·0	100	16·6	71·3	4·3
0·10	0·90	1·00	0·04	19·4	16·9	1·0	49·9	2·5	98	18·2	69·0	3·8
0·30	2·00	1·80	0·03	38·8	35·0	5·1	20·4	3·7	97	36·9	68·9	1·9
0·30	2·10	1·90	0·03	40·3	36·3	1·4	24·7	3·6	97	38·3	64·0	1·7
—	—	—	—	12·6	11·6	3·7	51·1	—	97	12·1	69·0	5·7
0·13	2·50	1·40	0·07	11·6	10·1	3·9	45·9	1·4	86	10·8	56·5	5·2
0·20	2·80	1·50	0·09	10·9	8·9	2·6	37·4	2·2	77	9·9	42·6	4·3
—	—	—	—	11·0	9·0	2·8	36·9	2·2	77	10·0	42·6	4·3
—	—	—	—	12·2	8·2	1·1	21·4	11·4	72	10·2	32·2	3·0
2·77	0·51	1·54	0·34	9·9	6·3	1·2	18·4	13·4	65	8·1	27·1	3·0
2·00	0·60	2·00	—	9·3	6·6	1·5	30·5	12·8	92	8·0	49·3	6·0
1·10	0·47	1·76	0·41	5·4	4·5	0·8	25·3	18·2	86	5·0	40·5	8·0
1·00	0·43	1·60	0·37	3·4	2·8	0·7	24·5	17·9	76	3·1	35·6	11·0
—	—	—	—	2·4	1·6	0·6	25·4	16·8	72	2·0	32·5	16·0
—	—	—	—	6·6	4·2	1·7	23·6	12·4	78	5·4	34·7	7·0
—	—	—	—	10·9	7·8	2·1	25·2	10·7	81	9·3	39·6	4·3
2·00	0·60	1·80	—	7·9	6·1	0·7	31·1	12·2	88	7·0	45·0	6·0
2·00	0·60	1·80	0·30	5·0	3·9	0·6	30·4	15·1	84	4·5	42·8	10·0
—	—	—	—	3·9	3·1	0·6	32·0	15·7	85	3·5	44·3	13·0

FOOD (1)	Dry Matter (2)	Crude Protein (3)	Ether Extract (Oil) (4)	Carbohydrates: Nitrogen-free Extractives (Soluble) (5)	Carbohydrates: Crude Fibre (6)	Ash (7)
	AVERAGE COMPOSITION PER CENT. AS SHOWN BY ANALYSIS					
II. COARSE FODDERS—continued						
(B) STRAWS						
Barley	86·0	3·3	1·8	42·4	33·9	4·6
Bean (including pods)	86·0	4·5	0·8	33·0	43·1	4·6
Oat, spring	86·0	2·9	1·9	42·4	33·9	4·9
Pea	86·4	9·0	1·6	33·7	35·5	6·6
Rye	86·0	3·2	1·6	41·7	36·9	2·6
Wheat, winter	86·0	2·1	1·3	40·7	36·6	5·3
III. SUCCULENT FOODS						
(A) GREEN FOODS						
Cabbage, drumhead	11·0	1·5	0·4	5·9	2·0	1·2
Cabbage, open-leaved	15·3	2·5	0·7	8·1	2·4	1·6
Kale, marrow-stem, unthinned	14·0	2·2	0·5	6·9	2·5	1·9
Kale, thousand-headed	15·8	2·2	0·4	8·4	3·1	1·7
Rape	14·1	2·8	0·8	5·7	3·5	1·3
(B) ROOTS AND TUBERS						
Carrots	13·0	1·2	0·2	9·3	1·4	0·9
Kohl Rabi	12·7	2·0	0·1	8·2	1·4	1·0
Mangolds, yellow fleshed globe	13·2	1·2	0·1	10·2	0·8	0·9
Potatoes	23·8	2·1	0·1	19·7	0·9	1·0
Sugar beet	23·4	1·1	0·1	20·4	1·1	0·7
Fodder beet	18·2	1·1	0·1	15·2	1·0	0·8
Swedes	11·5	1·3	0·2	8·1	1·2	0·7
Turnips	8·5	1·0	0·2	5·7	0·9	0·7
(C) SILAGE						
Clover	20·0	4·1	1·1	6·5	6·0	2·3
Grass, leafy	20·0	3·5	1·0	9·0	5·0	1·8
Grass, early flowering	25·0	3·2	0·9	11·6	7·0	2·3
Grass, full flower	25·0	2·9	0·7	10·9	7·9	2·7
Kale, marrow-stem	15·9	2·0	0·5	7·2	3·7	2·5

MINERAL COMPOSITION PER CENT.				DIGESTIBLE NUTRIENTS PER CENT.					CALCULATED FROM DIGESTIBLE NUTRIENTS			
							Carbohydrates					
Lime (CaO)	Phosphoric Acid (P_2O_5)	Potash (K_2O)	Chlorine (Cl)	Crude Protein	True Protein	Oil	Soluble	Fibre	V Number	Protein Equivalent (P.E.)	Starch Equivalent (S.E.)	Ratio S.E. : P.E.
(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(90)
0·50	0·20	1·20	0·35	0·8	0·6	0·6	22·5	18·3	54	0·7	23·0	32·9
1·20	0·30	1·90	—	2·2	1·3	0·5	22·0	18·7	43	1·8	19·0	10·5
0·36	0·18	1·50	0·30	1·0	0·8	0·6	19·4	18·3	50	0·9	20·0	22·2
1·60	0·40	1·00	—	4·3	3·4	0·7	18·5	13·7	45	3·9	17	4·4
0·22	0·16	0·50	—	0·6	0·4	0·8	20·0	20·3	36	0·5	15	30
0·29	0·13	0·80	0·20	0·1	—	0·4	15·0	18·3	38	—	13	—
0·20	0·10	0·40	0·02	1·1	0·7	0·2	4·6	1·4	94	0·9	6·6	7·3
0·25	0·15	0·50	—	1·8	1·2	0·4	6·5	1·7	94	1·5	9·5	6·3
0·43	0·12	0·55	0·21	1·7	1·1	0·3	6·1	1·6	93	1·4	9·1	6·5
0·39	0·13	0·52	0·16	1·7	1·2	0·2	7·5	1·8	92	1·5	10·3	6·9
0·20	0·15	0·30	—	2·0	1·3	0·5	3·9	1·9	87	1·7	6·9	4·0
0·09	0·11	0·30	—	0·8	0·4	0·1	8·9	0·7	87	0·6	8·8	14·7
0·13	0·13	0·35	0·06	0·7	0·3	—	7·4	0·6	90	0·5	8·3	16·6
0·02	0·09	0·45	0·16	0·7	0·1	—	9·4	0·3	70	0·4	6·8	17·0
0·03	0·18	0·60	0·04	1·1	0·6	—	17·7	—	100	0·9	18·5	20·6
0·05	0·10	0·35	0·06	0·8	0·3	—	19·3	0·4	75	0·6	15·0	25·0
—	—	—	—	—	—	—	—	—	—	—	—	—
0·08	0·08	0·30	0·04	1·1	0·3	—	7·5	0·8	85	0·7	7·3	10·4
0·07	0·09	0·30	0·04	0·6	0·2	—	5·2	0·3	77	0·4	4·4	11·0
—	—	—	—	2·7	1·6	0·6	4·7	3·2	81	2·1	8·9	3
—	—	—	—	2·8	1·2	0·5	7·2	4·0	89	2·0	12·4	4
—	—	—	—	2·1	0·6	0·6	9·0	5·6	85	1·4	14·5	7
—	—	—	—	1·2	0·5	0·5	6·9	5·8	79	0·9	11·4	10
—	—	—	—	1·5	1·0	0·4	6·1	2·8	90	1·3	9·8	7

FOOD (1)	AVERAGE COMPOSITION PER CENT. AS SHOWN BY ANALYSIS: Dry Matter (2)	Crude Protein (3)	Ether Extract (Oil) (4)	Carbohydrates: Nitrogen-free Extractives (Soluble) (5)	Carbohydrates: Crude Fibre (6)	Ash (7)
III. SUCCULENT FOODS—continued						
Lucerne	17·0	3·7	1·4	4·8	5·0	2·1
Maize	20·0	2·2	1·2	10·7	4·7	1·2
Pea haulm and pods	25·0	3·7	1·5	9·1	6·4	4·3
Potato, steamed	25·0	2·4	0·3	19·2	0·8	2·3
Potato haulms	25·0	3·2	2·7	9·1	4·4	5·6
Sugar beet tops	25·0	2·6	0·8	9·9	3·7	8·0
Vetch-oat	25·0	3·4	0·7	10·2	7·8	2·9
(D) MISCELLANEOUS						
Brewers' grains, wet	32·4	7·5	2·8	14·6	6·1	1·4
Distillers' grains, wet	26·2	8·4	3·0	10·4	3·6	0·8
Lucerne, in bud	22·0	4·5	0·5	9·0	6·2	1·8
Red clover, beginning to flower	19·0	3·4	0·7	8·0	5·3	1·6
Sugar beet pulp, wet	11·6	1·0	0·2	7·2	2·3	0·9
Vetches, early flowering stage	17·5	3·2	0·5	7·2	5·1	1·5
White clover, beginning to flower	18·5	4·4	0·8	6·9	4·3	2·1
IV. GRASSLAND						
(A) PASTURE GRASS						
Very leafy	18·0	4·0	0·6	7·5	3·6	2·3
Leafy	19·0	3·3	0·5	8·5	4·5	2·2
Little stem, early flowering stage	21·0	3·0	0·7	9·8	5·4	2·1
Stemmy, flowering stage	23·0	2·4	0·5	11·7	6·2	2·2
Seed set, full flower	25·0	2·1	0·6	13·1	7·4	1·8
(B) ARTIFICIALLY DRIED CROP						
Grass, very leafy	90·0	18·7	3·0	40·6	17·7	10·0
Grass, leafy	90·0	15·0	2·6	40·7	20·9	10·8
Grass, little stem, early flowering	90·0	12·1	2·2	42·3	24·4	9·0
Grass, stemmy, flowering	90·0	10·4	2·2	42·7	24·4	10·3
Lucerne or clover, bud stage	91·0	22·3	2·9	36·4	18·0	11·4
Lucerne or clover, early flowering	91·0	16·2	2·4	37·7	24·5	10·2
Clover meal	90·0	10·5	1·4	44·1	26·4	7·6

MINERAL COMPOSITION PER CENT.				DIGESTIBLE NUTRIENTS PER CENT.					CALCULATED FROM DIGESTIBLE NUTRIENTS			
							Carbohydrates					
Lime (CaO)	Phosphoric Acid (P_2O_5)	Potash (K_2O)	Chlorine (Cl)	Crude Protein	True Protein	Oil	Soluble	Fibre	V Number	Protein Equivalent (P.E.)	Starch Equivalent (S.E.)	Ratio S.E. : P.E.
(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
—	—	—	—	2·5	1·5	0·7	3·3	2·1	81	2·0	7·0	3
—	—	—	—	1·4	0·6	1·0	7·5	3·2	90	1·0	12·1	9
0·54	0·16	—	0·11	2·1	0·2	1·4	6·3	3·6	83	1·2	11·5	5
—	—	—	—	1·5	0·7	0·1	17·2	0·4	100	1·1	18·6	12
—	—	—	—	1·2	0·3	1·2	5·0	1·7	86	0·7	8·3	7
—	—	—	—	1·6	0·2	0·3	7·8	2·7	91	0·9	10·8	7
—	—	—	—	1·9	0·9	0·5	6·7	4·8	78	1·4	10·8	6
0·10	0·40	0·05	0·02	5·5	5·2	2·4	9·1	2·4	86	5·3	18·4	3·5
0·10	0·40	0·05	—	6·2	5·8	2·6	6·4	1·7	86	6·0	16·2	2·7
0·77	0·14	0·56	0·05	3·6	2·4	0·1	6·8	3·1	84	3·0	11·3	3·8
0·40	0·15	0·50	0·05	2·5	2·1	0·5	6·3	2·9	86	2·3	10·3	4·8
0·36	0·05	0·18	—	0·5	0·30	0·10	5·4	1·2	90	0·4	6·5	16·2
0·50	0·15	0·50	—	2·2	1·4	0·3	4·9	2·3	83	1·8	7·5	4·1
—	—	—	—	2·8	1·9	0·5	4·7	2·6	88	2·4	8·8	3·7
—	—	—	—	3·3	2·3	0·3	6·1	3·0	88	2·8	10·8	4
0·35	0·20	0·75	0·24	2·5	1·8	0·3	6·7	3·6	87	2·2	11·3	5
—	—	—	—	2·1	1·6	0·4	7·5	4·2	86	1·9	12·2	6
—	—	—	—	1·6	1·3	0·3	8·4	4·6	85	1·5	12·7	9
—	—	—	—	1·3	1·0	0·3	9·3	4·8	81	1·2	12·8	10
1·35	1·00	—	—	14·1	13·0	1·7	30·5	13·3	90	13·6	54·1	4
1·20	0·90	—	—	10·0	8·6	1·5	31·0	15·9	88	9·3	51·7	6
—	—	—	—	7·3	6·4	1·1	31·4	18·8	87	6·8	51·2	7
—	—	—	—	5·8	5·1	1·2	30·9	18·6	87	5·5	49·5	9
—	—	—	—	15·9	11·2	1·3	28·4	9·5	94	13·6	50·1	4
—	—	—	—	11·6	9·3	0·7	27·8	11·2	88	10·5	44·1	4
—	—	—	—	5·7	4·2	0·6	30·5	14·0	76	5·0	42·0	8

The digestibility of foods also varies with the manner of preparation, for example, the protein of overheated silage is less readily digested than that of a well-made sample and the digestibility of hay, overheated in the stack, is also impaired. Cooking may improve the palatability of certain foods and increase the digestibility of carbohydrates but it lowers the digestibility of protein.

Ruminants, by virtue of the microflora of the rumen and the large capacity of this organ, have a greater capacity than non-ruminants to utilise fibrous foods. The comparative inefficiency of the horse in making use of crude fibre is probably due to the reduced size of the digestive tract and to the fact that fibre digestion occurs largely in the caecum after gastric and small intestinal digestion has taken place.

ENERGY RELATIONSHIPS

The purpose of food is, first, to keep the animal alive and, secondly, to enable it to produce work, growth, fat, milk, eggs or the young of its species. That part of its diet which is used to keep it alive is called a maintenance food; that which is given in addition to the maintenance allowance is called a production food.

The amount of energy which a food contains can be determined by measuring the heat emitted when it is completely oxidised in a bomb calorimeter. This value is usually expressed in terms of calories per unit mass of food.

One calorie is the amount of heat required to raise the temperature of 1 gram of water through 1° C. and 1 kilocalorie (1 Cal.) represents the amount of heat required to raise one kilogramme (1000 g.) of water through 1° C. The latter unit is used almost exclusively in animal nutrition but in the United States of America the Therm (1000 Cal. or Kilocalories) is employed.

The energy liberated by a food on complete oxidation is variously known as the Gross Energy, Gross Chemical Energy, Energy of Combustion, Chemical Energy or Total Energy.

The amount of this energy which the animal can utilise depends upon the extent to which digestion takes place. Hence the energy remaining after deducting the energy value of the undigested faecal residues is known as the Digestible Energy.

In addition to losses in the faeces a considerable amount of energy is lost in the form of methane produced by bacterial fermentation in the rumen and also as unoxidised metabolic residues, e.g., urea and uric and hippuric acids in the urine. When the total energy of the excrement, solid, liquid and gaseous, is deducted from the Gross Energy the amount of energy available to the animal is obtained; it is known as the Metabolisable Energy. Thus:—

1. Gross Energy—Energy of faecal residues = Digestible Energy.
2. Digestible Energy—Urinary and gaseous energy = Metabolisable Energy.
3. Gross Energy—Total energy of excrement = Metabolisable Energy.

The energy required to maintain the animal body in a resting position and to supply heat lost by respiration, by the work of the involuntary muscles, and by the temperature difference between the animal and its environment, i.e., by conduction, convection and radiation, is known as the metabolisable energy. This energy may be regarded as being completely useful to the animal.

The gross energy or heat of combustion of fats, proteins and carbohydrates may be taken as 9·3, 5·8 and 4·1 Cal./g. respectively. After allowing for the energy value of excrement these groups of nutrients have the following heat values or metabolisable energy values to the animal:—

Oil and fat	... ...	8·8 Cal./g.	≡ 4000 Cal./lb.
Proteins	... ...	4·7	≡ 2133
Carbohydrate	... ...	3·7	≡ 1707

Taking the heat value of carbohydrate (starch) as 1, the comparative values of protein and fat become respectively 1·25 and 2·3. Consequently the metabolisable energy of a food may be expressed in terms of heat (Calories or Therms) or of starch. Thus for linseed cake:—

Digestible Nutrient	per cent. Factor Starch Value	Heat Value in Cal.
Protein equiv.	24·5 × 1·25 = 30·63	24·5 × 2133 = 52,258
Oil	9·0 × 2·30 = 20·70	9·1 × 4000 = 36,000
Carbohydrate + fibre.	30·0 × 1·00 = 30·00	30·0 × 1707 = 51,210
	81·33	139·468

The figure obtained in the first column represents the maintenance starch equivalent of the food; it is in fact an expression of the energy made available to an animal, the metabolisable energy, from a food in terms of starch.

Since animals rarely receive the minimum energy or food allowance necessary for maintenance, surplus or supplementary energy will be available for productive purposes such as growth and formation of fat, wool, milk and other body products. This additional energy has a lower value to the animal than that given for maintenance since part of it is expended in the processes of digestion and conversion to assimilable nutrients. The heat so formed is surplus to the body's requirements and so it is valueless to the animal. Moreover, it has been shown that the utilisation of this supplementary energy causes an increase in the rate of metabolism as shown by an increased production of carbon dioxide and heat. Of the food constituents proteins in particular exert a stimulating effect on the energy exchanges in the body. The increased rate of metabolism as a result of the consumption of large amounts of protein is usually referred to as *Specific Dynamic Action*. The real production value of a food is therefore the metabolisable energy less the thermal energy produced during its conversion to assimilable form; it is known as the *Net Energy*.

Since some foods are more easily digested and converted than others the thermal energy produced in the process is variable and consequently their net energy values will be different. The discrepancy between metabolisable and net energy values is greatest with fibrous foods, in fact the horse expends more energy on the digestion of wheat straw than is made available from that food. Such a material therefore possesses a negative net energy value. Conversely, milk, which is highly digestible, has a high metabolisable energy value and its net energy is also high.

Net energy values therefore vary with the food and with the animal consuming it. They also vary with the purpose for which the food is provided, i.e., for maintenance, growth or milk or fat production. It has been shown that the conversion of metabolisable energy to milk is 69·3 per cent. efficient while the efficiency of its conversion for fattening is only 57·5 per cent. The net energy values also vary with the plane of nutrition, animals on low and sub-maintenance

standards of feeding making more efficient use of this food. Furthermore, the net energy value of a food also depends on the nature of other foods fed in conjunction with it.

Net energy values as determined by Armsby in America and expressed in terms of starch possibly underestimate the value to the animal of the supplementary food, particularly fibrous foods, by the assumption that it makes no contribution to maintenance. Some part of it may be utilised to maintain the body temperature and would thus prove useful.

FAT-PRODUCING CAPACITY OF FOODS

STARCH VALUES

The effect of feeding known weights of pure digestible nutrients in addition to the basal or maintenance rations of store bullocks was determined by Kellner, a German nutritionist. The resultant gains in body weight were expressed in terms of fat and from this the fat-producing power of the pure nutrients of which the foods were composed was found. It was discovered in addition that the fat-producing capacity of oils and fats varied with their source and that the digestible fibre had the same fat-producing value as starch. The following results were obtained:—

Pure Digestible Nutrient	Amount of Body Fat formed per 1 lb. nutrient fed lb.
Carbohydrate	0·248
Protein	0·235
Fat from coarse fodders... ...	0·474
Fat from cereals	0·525
Fat from oil seeds	0·598

Using these values it is possible to calculate the fat-forming power of foods thus:—

Linseed Cake

Digestible Nutrient	Per cent.		Factor		Fat formed lb.
Protein equivalent	24·5	×	0·235	=	5·76
Oil	9·0	×	0·598	=	5·38
Carbohydrate + fibre ...	30·0	×	0·248	=	7·44
					18·58

Therefore 100 lb. linseed cake have a theoretical fat-forming value of 18·58 lb.

Submission of the above theoretical factors to practical test showed that the amount of fat actually formed was generally less than that calculated. Moreover, it was seen that while agreement was close with concentrated foods discrepancies were most marked with roughages due to the fact that energy was expended in dealing with the indigestible portion of the food.

A relationship was established between the fibre content of a food and its actual fat-forming capacity, i.e., of the ability of the individual nutrients of a food to function as if they were pure. This relationship is expressed as a percentage of efficiency or availability and is known as "V," the value number. For linseed cake this V number is 97. hence, in the example above, the actual fat-producing value of linseed cake is

$$\frac{18{\cdot}58 \times 97}{100} = 17{\cdot}74$$

The numerical value of V is influenced by the nature and quality of the food and by the percentage of crude fibre.

STARCH EQUIVALENT

As an alternative to expressing the fat-producing power of the digestible nutrients in 100 lb. of a food in terms of fat, Kellner suggested that soluble carbohydrate, e.g., starch, be used as the unit. Thus the number of pounds of starch necessary to produce the same amount of fat as 100 lb. of a particular food was called the Starch Equivalent. The Starch Equivalents of carbohydrate, fat and protein can therefore be calculated from Kellner's comparative values of their fat-producing capacities:—

Pure Digestible Nutrient	Fat formed for each 1 lb. nutrient (lb.)	Fat formed relative to starch	Starch Equivalent
Carbohydrate ...	... 0·248	$\frac{0{\cdot}248}{0{\cdot}248}$	1·00
Protein... ...	... 0·235	$\frac{0{\cdot}235}{0{\cdot}248}$	0·95

Pure Digestible Nutrient	Fat formed for each 1 lb. nutrient (lb.)	Fat formed relative to starch	Starch Equivalent
Fat from coarse fodders	0·474	$\frac{0·474}{0·248}$	1·91
Fat from cereals ...	0·525	$\frac{0·525}{0·248}$	2·12
Fat from oil seeds ...	0·598	$\frac{0·598}{0·248}$	2·41

Using the above factors the starch equivalent of a food may be calculated. Once again, to take linseed cake as an example:—

Digestible Nutrient	Per cent.	Factor	Theoretical S.E.
Protein equivalent	24·5	0·95	23·27
Oil	9·0	2·41	21·69
Carbohydrate + Fibre.	30·0	1·00	30·00
			74·96

Since V = 97

Actual Starch equivalent will be $\frac{74·96 \times 97}{100} = 72·7$

This is known as the production Starch Equivalent.

For all practical purposes starch equivalent and net energy may be regarded as similar values. Therefore they may be converted the one into the other since 1 lb. starch yields 1071 Cal. of net energy.

While the V numbers for concentrated foods of high digestibility were in accord with results obtained in practice, a different procedure was recommended by Kellner for coarse and green fodders for which V is numerically small, as shown on page 368.

While starch equivalents are useful as a basis for the evaluation of foods their limitations must be remembered. For example, they make no distinction between that part of an animal's food which supplies energy, carbohydrates and fats, and that which is required for body building purposes, namely, proteins. Secondly, because of the laborious nature of the experimental work involved, many of the net energy

Coarse fodder	Crude Fibre per cent.	lb. S.E. to be deducted for each 1 per cent. Crude Fibre
Hay and Straw (long)	—	0·58
Hay and Straw (chaffed)	—	0·29
Green fodders	More than 16	0·58
	14–16	0·53
	12–14	0·48
	10–12	0·43
	8–10	0·38
	6–8	0·34
	4–6	0·29

values have been computed and not determined. Thirdly, results obtained by Kellner from feeding animals on sub-maintenance levels have been applied to milk production, work and growth and to all classes of livestock. Moreover, no account is taken of the relative ability of different species to utilise to a greater or less extent particular nutrients. For example, poultry, pigs and horses are unable to digest crude fibre as efficiently as ruminants. Further limitations are the variability in composition of foods due to seasonal, soil, manurial and other factors and the presumption that vitamins and minerals will be present in adequate amounts.

Total Digestible Nutrients—Because of the variable efficiency of conversion of metabolisable energy in milk production or fattening, i.e., because the net energy per therm of metabolisable energy is variable, net energy values as a basis of feeding are no longer used in the United States of America. There, requirements are stated in terms of metabolisable energy and/or Total Digestible Nutrients (T.D.N.) which is calculated thus:—

T.D.N. = % Dig. Carbohydrate + % Dig. Fibre + (% Dig. Oil × 2·25) + % Dig. Crude Protein.

The metabolisable energy of a ration may be calculated on the assumption that 1 lb. total digestible nutrients of a good mixed ration has a metabolisable energy value of 1,616 Calories.

Scandinavian Food Unit System—In this system requirements are stated in units of 1 kg. of barley meal, the food requisite to the production of 3 kg. of average quality milk. Recognition of the varying efficiencies of conversion of food for fat and milk production is made together with allowances for variation in the quality of foods above or below a medium standard. No attention, however, is paid to the vitamin or mineral status of the diet nor is adequate attention paid to the protein quality.

Nutritive Ratio—Whatever system be used to express the energy value of a food it must be remembered that all constituents, fats, proteins and carbohydrates, contribute towards the total. It has been shown that fats and carbohydrates may be regarded as energy yielding nutrients and to this extent they are interchangeable, but the animal's essential need for protein can only be supplied from the food protein. Some foods are rich in carbohydrate and/or oil and have low percentages of protein while others are rich in protein with a relatively smaller proportion of carbohydrate. The balance of a food in respect of these constituents is expressed by the Nutritive or Albuminoid Ratio (N.R.) which is:—

$$\text{N.R.} = \frac{\text{Digestible non-protein constituents}}{\text{Dig. Protein} + \text{other Dig. Nitrog. Constituents}}$$

$$= \frac{\text{Energy}}{\text{Effective Protein}}$$

$$= \frac{\%\ \text{Dig. Carbohydrate} + \%\ \text{Dig. C. Fibre} + (\%\ \text{Dig. Oil} \times 2{\cdot}3)}{\%\ \text{Crude Protein}}$$

(Digestible Oil is multiplied by 2·3 because 1 lb. yields 2·3 times as much heat energy as an equal weight of starch.)

Ratios of 4 : 1 are regarded as narrow, i.e., they are high in protein; ratios of 8 : 1 are wide, indicating foods rich in fats and carbohydrates. Well-balanced foods have ratios of about 6 : 1. The feeding of young growing stock

necessitates adequate supplies of protein, hence a narrow ratio is suitable; the adult animal, which utilises energy for fat formation and may make comparatively little growth, will require a wide ratio.

For convenience, the ratio of starch equivalent to protein equivalent is sometimes used. It is not identical with the nutritive ratio and is calculated thus:—

$$\frac{\text{S.E.}}{\text{P.E.}} = \frac{\%\ \text{Dig. Carb.} + \%\ \text{Dig. Fib.} + (\%\ \text{Dig. Oil} \times 2{\cdot}3) + (\%\ \text{P.E.} \times 0{\cdot}94)}{\%\ \text{P.E.}}$$

NUTRITIVE REQUIREMENTS OF STOCK

The rationing of farm animals involves consideration of their maintenance and production requirements. In the calculation of rations it is convenient but unjustifiable to keep these separate. The ration allocated to the animal is utilised for both purposes. Concentrates will make some contribution to maintenance requirements and bulky foods may contribute to the production of growth or milk.

The maintenance requirement of an animal varies according to its live weight to the power $\frac{3}{4}$. Different workers have reported that between 4·7 and 7·0 lb. of starch equivalent per day are necessary for the maintenance of a bullock of 1000 lb. live weight. The standard now generally accepted is 6 lb. per day for an animal of that type and weight. From this value the maintenance requirements of animals of different weights can be calculated.

Energy requirements for the production of work are not known with certainty. For the production of 1 lb. of fat Kellner determined that 4 lb. of starch were necessary. Live weight gain in young animals includes protein (flesh) as well as fat; in mature stock, growth is relatively small and live weight increase is due to fat rather than to protein. Moreover, as the animal increases in age less of the live weight gain is due to water. To produce 1 lb. of live weight increase in fattening animals under 2 years of age about 2 lb. of S.E. are required. For fattening bullocks over 2 years of age the amount will depend upon their condition and as much as 4 lb. S.E. may be required to produce 1 lb. of live weight gain.

The starch equivalent necessary for the production of 1 gallon of milk of average quality (3·7 per cent. fat) is about

2·5 lb. For Channel Island or other milk with high fat content 3 lb. S.E. per gallon would be required.

The protein required for maintenance can be ascertained from the nitrogen content of the urine of fasting animals; it is also proportional to the body weight to the ¾ power. The minimum requirement is probably between 0·2 and 0·3 lb. of protein per 1000 lb. live weight. Present standards take into account the need for exceeding minimum requirements and the varying biological values of the proteins of which the ration is composed and it is customary to allow 0·6 lb. of protein equivalent for an animal of 1000 lb. live weight. The protein requirements for maintenance of animals of other live weights can thus be calculated from this value. They are applicable to all classes of farm livestock. It will be observed that ratio of S.E. to P.E. for maintenance is 10 : 1.

The requirements of protein for productive purposes will vary with the body product. Theoretically neither the production of work nor fat should require supplies of protein. In practice it is found that unless protein be supplied inadequate use is made of the constituents which supply energy. Hence it is usual to consider the ration as a whole and maintain a nutritive ratio not wider than 10 : 1. For growth and for fattening, or for both purposes, the ratio of S.E. to P.E. in the ration will depend upon the age of the animal: it varies from 5 : 1 for cattle aged 3 months to 8 : 1 for cattle aged 24 months.

The protein content of milk does not vary appreciably although it is greater in milk with a high percentage of fat. Milk of average quality contains about 3·4 per cent. protein which is approximately equivalent to 0·34 lb. of protein per gallon. The minimum requirement per gallon of milk will therefore be 0·34 lb. Making due allowance for the biological value of the food protein being less than 100 a standard of 0·5–0·6 lb. of protein equivalent per gallon of average quality milk (3·7 per cent. fat; 3·4 per cent. protein) is generally accepted. For milk with higher percentages of fat increased amounts of protein are allowed, thus, Channel Island breeds require about 0·7 lb. of protein equivalent per gallon of milk.

In addition to possessing the correct balance of energy to protein a ration must satisfy the animal's appetite. For

cattle, sheep and horses the provision daily of an amount of food, expressed in terms of dry matter, equivalent to 2·5–3 per cent. of the body weight is satisfactory. For larger animals and for high yielding cows the higher figure may require to be exceeded.

The mineral matter and vitamin content of the food must be considered; it should also be palatable and mildly laxative to facilitate the elimination of waste products. The effect of food fat on the properties of the body fat or milk fat and the possibility of certain foods producing taints in milk must also be borne in mind.

In the succeeding pages it will be seen how the feeding standards outlined above are applied in the computation of rations.

FEEDING STUFFS

THE following notes are a brief guide to some foods in common use.

CEREALS

Barley—Barley is a safe food for all stock. Fed to pigs as a coarsely ground meal it may form 60–80 per cent. of a fattening pig's ration. It produces a firm fat of good quality. Barley may also be fed to all classes of cattle and sheep either rolled or coarsely ground. If used in place of oats for horses it should not usually replace more than one-half of the oats.

Wheat—Wheat has about the same energy value as barley but a higher protein content. When finely ground the meal becomes pasty. Do not feed fresh wheat to horses nor give them large amounts. It may form 25–30 per cent. of the concentrate ration for cattle and sheep. A rather larger proportion than this may be included in meals for older fattening pigs and breeding pigs. It is a standard food for poultry.

Oats—Oats are very palatable and very safe. They are often the only cereal fed to horses for whom they are crushed or fed whole. The higher fibre content makes oats rather less suitable for pigs especially youngsters although good quality grain finely ground may form 30–50 per cent. of the meal ration of older pigs. Crushed oats are an excellent food for cattle and sheep, while Sussex Ground Oats are widely fed to poultry. Oats have a good effect on carcase quality and fat but should not be fed freshly harvested.

Maize—Yellow Maize contains useful amounts of carotene, the precursor of vitamin A. Excessive feeding of maize to fattening animals results in a soft yellowish fat. When it is economical to do so maize may replace a part of the cereal ration of all stock.

Rye—Rye is rather less palatable than other cereals though its energy and protein content is similar to barley and wheat. Rye may contain a fungus—ergot, which is

poisonous and may cause abortion. Like all cereals it will cause digestive disorders if fed fresh.

Flaked Maize—This food is very digestible and palatable and higher in energy and protein than most cereals. A safe food for all stock but it is often rather expensive.

Wheat Bran—Usually contains 9–10 per cent. crude fibre, is palatable, bulky, rather laxative when fed as a mash and has medicinal properties. It is more usually fed to ruminants than to pigs or poultry. The phosphorus content is high but the amount of calcium small.

Weatings—Weatings have a rather higher energy content and lower protein content than bran and different grades vary in the amount of crude fibre. Weatings are commonly used in pig meals where they may form up to 60 per cent. or so of the meal. They may be fed with safety to all classes of stock but have rather poor supplies of minerals and vitamins.

Brewers' Grains and Distillers' Grains—These are obtained in both wet and dry form and the starch equivalent and protein equivalent values of each sort are shown below:—

	S.E.	P.E.
Fresh Brewers' Grain	18·4	5·3
Fresh Distillers' Grain	16·2	6·0
Dried Brewers' Grain	48·3	12·5
Dried Distillers' Grain	57·2	19·1

Wet grains are very palatable and frequently fed to milking cows. About 15 lb. supplies adequate energy and more than sufficient protein for a gallon of average quality milk. Dry grains are also suitable for cows or ewes though distillers' grains are so high in protein that they are not balanced for milk production. Dry grains may be fed to other classes of cattle or sheep and may form up to 30 per cent. of the concentrate ration of horses.

Beans and Peas—Both these leguminous seeds have an energy value similar to cereals but contain more protein with a starch equivalent : protein equivalent ratio of about 3 : 1. The proteins are of high value for milk production and growth and these foods though rich in phosphorus supply little lime. They may be fed to all classes of stock.

CONCENTRATES

Decorticated Groundnut Cake or Meal—A palatable safe food high in protein and energy and may be fed to all classes of stock. Its proteins are of high biological value and it is very popular as a protein supplement.

Soya Bean Cake and Meal—A safe palatable food. Not quite so high in protein or energy as groundnut. May be fed to all classes of stock. The extracted meal has a rather lower energy value than the other. It is normally used as a protein supplement.

Decorticated Cotton Cake or Meal—Rich in protein with an S.E. : P.E. ratio of approximately two to one. Not very palatable and not suitable for sheep under about four months of age or cattle under six months. Only feed small amounts to pregnant animals, to young stock or to pigs because of the presence of Gossypol that may cause a fatal illness. Cotton cakes and meals are somewhat costive.

Coconut Cake—This food has a reasonably high protein content and the ratio of S.E. : P.E. is correct for milk production and for growth. It is frequently included in rations fed to dairy cows and when fed to fattening pigs or cattle helps to produce a hard white body fat.

Palm Nut Kernel Cake or Meal—This also is a food properly balanced for milk production. Like coconut cake or meal it helps to produce a hard white fat. It is a safe food and though reputed to be somewhat unpalatable this idea has been rather over-emphasised. Palm Kernel cake or meal may be fed to all classes of stock.

Linseed—Both cake and meal are safe and very palatable foods, and may be fed to all classes of livestock. Linseed cake or meal is a very popular food for calf feeding but care is required if a gruel of linseed is to be made. The water used must be either cold or boiling. Merely warm water may result in the production of prussic acid. Fed in excessive amounts to fattening animals it may produce a rather soft yellow fat.

FOODS OF ANIMAL ORIGIN

Blood Meal—A food high in protein, of high biological value but of low mineral content. Blood meal should be

used in moderation and if replacing a food richer in minerals then a mineral supplement will be needed.

Meat Meals and Meat and Bone Meals—The protein of these foods is of high biological value but the amount of protein is variable. Whilst meat meal is low in minerals, meat and bone meal is high. Thus meat and bone meal is good for growing and milking animals. These are safe and palatable foods and may often be cheaper per unit of the protein than alternative sources.

Whale Meat—A palatable high protein food and a good source of minerals. Often used in lieu of fish meal or meat and bone meal. To a great extent the choice depends on unit costs of the protein.

Fish Meal—There are two sorts, white fish meal and herring meal. The former is higher in protein but lower in energy and oil. Both supply high quality protein and are excellent foods for breeding and growing animals. Fish meal rarely exceeds 10 per cent. of concentrate rations and whilst herring meal is suitable for sows, boars and ewes, it is better to feed the white fish meal to milking cows and fattening pigs. Good quality fish meal has no ill effects on milk or body fat but it is often more expensive per unit of protein than alternative animal proteins.

Separated Milk—This food has an energy content about one-half that of whole milk and if it is used as a substitute for whole milk in calf rearing this energy deficiency needs to be made good. One way is to add cereals to the separated milk, for example, $\frac{3}{4}$–1 lb. of oats with each gallon of separated milk will be adequate. In practice, however, very young animals may not be able to eat sufficient of the cereal. Separated milk is an excellent food for young pigs and fed in conjunction with a cereal weatings mixture can form the ration of fattening pigs until they are slaughtered. Dried separated milk powder may be included in the meals for young pigs or may be reconstituted.

Whey—Whey has much less energy and protein than whole milk. Moreover, the ratio of starch equivalent: protein equivalent is 10 : 1. It is often fed to fattening pigs and 1 gal. of whey will replace a little under 1 lb. meal. Whey may replace whole milk in calf rearing but the energy

and protein deficiency requires to be made good. This is difficult to do in practice due to the small appetite of the young calf. Do not feed sour whey.

ROOT CROPS

These are foods high in moisture and low in fibre. They are deficient in minerals and whilst supplying vitamin C contain little or no vitamin A.

Mangolds should be stored some weeks prior to feeding, less risk of taints in milk will arise from turnips if fed after milking, sprouted potatoes should not be fed and it is necessary to cook potatoes before feeding them to young and pregnant stock and to pigs. Feeding excessive quantities of roots to male sheep may cause urinary calculi.

Mangolds—Mangolds may be fed to all classes of stock. Approximately 40 lb. supply the same amount of starch equivalent as 6–7 lb. of good meadow hay. Sows can eat 20–30 lb. of mangolds daily and fattening pigs 5–10 lb. depending on their live weight. Fattening cattle may be fed 50–80 lb. daily.

Swedes—Swedes are also a safe food with a rather higher protein content than mangolds. Rates of feeding are similar to mangolds but swedes have a rather higher feeding value, 34 lb. containing the same starch equivalent as 40 lb. mangolds. Swedes or swedes and kale are popular folding crops for sheep.

Fodder Beet—This root has a higher dry matter content than swedes or mangolds. It may be fed to all stock but is more commonly given to pigs. Five to 6 lb. beet replaces 1 lb. cereal meal. It produces a hard white fat when fed regularly to fattening pigs. Beet may be introduced into the ration gradually and advisably not fed to pigs below 70–80 lb. live weight.

Potatoes—Raw potatoes are rather bitter, have a laxative effect and if used in excessive amounts may cause blowing and scouring. Cattle eat raw potatoes and cows may be given 25–30 lb., fattening cattle 40–50 lb. and sheep 4 lb. per 100 lb. live weight daily. Only small amounts should be given to horses but pigs can make considerable use of potatoes. For pig feeding they can be boiled or ensiled in large quantities and fed as required.

Four pounds of potatoes replace 1 lb. fattening meal and in feeding bacon pigs the meal need not exceed $2\frac{1}{2}$–3 lb. daily whilst potatoes increase to 12–14 lb. daily. Potatoes should be introduced gradually into the ration and the mineral and protein content of the meal adjusted. Cooked potatoes may be fed to poultry, for example, 4 oz. daily plus 4 oz. of dry food.

Green Crops—Green crops are high in moisture and low in fibre. They are valuable sources of calcium, potash, iron, magnesia but contain less phosphorus. They also contain vitamins A, B, C, and to a lesser degree D and E. Both the starch equivalent and the protein equivalent are higher than the root crops and the ratio of starch equivalent to protein equivalent rather narrower.

Cabbage—Cabbages are safe and palatable with the open leaf type having a rather higher food value than the drumhead. Cows may be fed 50 or 60 lb. daily, preferably after milking. Pigs enjoy cabbage and if boiled or steamed will eat more than when raw, for example, pigs could receive a meal allowance increasing to 4 lb. per day at 150 lb. live weight with cabbage introduced at 60–80 lb. live weight and thereafter fed to appetite.

Kale—One of the most valuable winter foods for cattle, it may be folded or cut and carted. Dairy cows frequently eat 50–60 lb. daily but larger breeds consume 84 lb. or more if required. For young growing cattle it is a valuable source of minerals and vitamins and a useful part of the maintenance ration. Sheep do well on kale. A ewe can eat 1–$1\frac{1}{4}$ cwt. per week and a teg of 100 lb. live weight will make a satisfactory live weight gain on a ration of 100 lb. kale and several pounds of hay weekly. A ration of 10 lb. hay and 65–70 lb. kale daily enables a 8 cwt. steer to put on 2 lb. weight per day. Chopped kale is a good food for pigs about 7–8 lb. replacing 1 lb. meal. Horses eat kale readily.

Sugar Beet and Fodder Beet Tops—The crown and leaves are very digestible. The dry matter is about twice that of kale and cabbage, the energy value about the same and the protein equivalent a little lower. Tops should be as free from soil as possible and allowed to wilt several days before being fed. They may be given safely to all

classes of stock. About 30 lb. having the same energy value as 40 lb. mangolds, 34 lb. swedes, 67 lb. hay or 35 lb. drumhead cabbage.

STRAW

All straws are very low in protein, minerals and vitamins, they are maintenance foods. Oat straw has a higher food value than others whilst wheat is the least useful. Oat straw is often fed to older store and fattening cattle and may be given to low yielding dairy cows. When fed to growing cattle care must be taken that the remainder of the ration contains adequate protein, minerals and vitamins. Oat straw may replace a little of the hay in the ration of idle horses. Bean and pea straw if harvested early are useful foods with pea straw the better of the two.

Grassland—The term covers a wide variety of sward types of varying productivity. Some pastures will fatten a bullock and two or three sheep per acre, whilst mountain grazing may only support a sheep on several acres. The food value of pasture varies from field to field and in the same field year by year, and seasonally throughout the year. Grass is most nutritious when young and leafy as its value falls rapidly as it grows to maturity.

The mineral content of herbage also varies, grasses are usually equally rich in calcium and phosphorus but legumes are richer in calcium. A good sward on a fertile soil contains adequate minerals for the needs of all stock excepting high yielding cows. The proteins of grass are of high biological value and pasture is a valuable source of carotene, the precursor of vitamin A. The following table illustrates the changes in food value of grass with increasing maturity.

Stage of Growth	D.M. per cent.	D.C.P. per cent.	S.E. per cent.	P.E. per cent.	Ash per cent.
Leafy grass	19	2·5	11·3	2·2	2·2
Early flowering stage	21	2·1	12·2	1·9	2·1
Flowery stage ...	23	1·6	12·7	1·5	2·2
Seed set	25	1·3	12·8	1·2	1·8

Good pasture well managed and grazed when leafy will provide for the needs of a cow yielding 4–5 gal. of milk daily. Fattening steers can gain weight at 2½–3 lb. per day and it can sustain the needs of milking ewes and fast growing lambs.

Hay—The term includes meadow hay, seeds hay, clover, lucerne and sainfoin hay. Oats and tares may also be made into hay and timothy may be grown for the purpose as a pure seeding. The food value of hay depends on the crop from which it is made, the botanical composition of the sward, the stage of maturity when cut and the efficiency of the making. The following table gives data regarding several types of hay.

	D.M. per cent.	S.E. per cent.	P.E. per cent.
Meadow hay (early flower)	85	40·5	5·0
,, ,, (flowering)	85	35·6	3·1
,, ,, (full flower)	85	32·5	2·0
Lucerne (full flower) ...	83·5	29	8·0
Seeds hay (medium clover)	85	42·8	4·5
Sainfoin (in flower) ...	83·5	37	8·6
Oats and tares	84	34·7	5·4

Hay is generally regarded as a maintenance food and can be safely given to all ruminants and horses.

So far as a starch equivalent in good meadow hay is concerned the following replacement table may be useful.

Seven pounds of meadow hay is equivalent in energy content to 40 lb. mangold, 34 lb. swede, 28 lb. kale, 30 lb. cabbage, 20 lb. grass silage, 10 lb. oat straw, 30 lb. sugar beet tops and 4¼ lb. of dried sugar beet pulp.

Dried Grass and Dried Lucerne—The feeding value is related to the crop dried and to the stage maturity when cut. The table illustrates these points:—

	D.M. per cent.	S.E. per cent.	P.E. per cent.
Grass—leafy	90	51·7	9·5
Grass—early flower, little stem	90	51·2	6·8
Grass—stemmy	90	49·5	5·5
Lucerne—bud stage ...	91	50·1	13·6
Lucerne—early flower ...	91	44·1	10·5

Leafy dry grass may be fed in lieu of concentrates to ruminants, for example, 5 lb. of leafy dried grass provides enough nutrients for the production of 1 gal. of average quality milk. Lucerne dried in the bud stage is best mixed with a cereal to obtain a proper balance between starch equivalent and protein equivalent, for example, 5 lb. of a mixture of 45 lb. oats and 35 lb. lucerne provide the nutrients for 1 gal. of average quality milk. Moderate amounts of dry grass meal can be included in the rations of breeding and fattening pigs.

These foods are valuable and costly and should be regarded as concentrates.

Silage—There are many types of silage and when made from grassland the food value falls as the sward becomes more mature. The following table gives the food value of several types of silage:—

	D.M. per cent.	S.E. per cent.	D.C.P. per cent.	P.E. per cent.
Clover	20	8·9	2·7	2·1
Leafy grass	20	12·4	2·8	2·0
Early flowering grass	25	14·5	2·1	1·4
Lucerne	17	7·0	2·5	2·0
Maize	20	12·1	1·4	1·0
Marrow stem kale ...	16	9·8	1·5	1·3
Vetch and oats ...	25	10·8	1·9	1·4

The section in this book on grassland discusses in detail the feeding of silage to various classes of stock.

It should be introduced into the ration gradually and troughs, etc., in which it is fed must be cleaned daily. Silage should not be fed in a shippen immediately before milking because of the risk of tainting milk.

In recent years considerable economy in the labour cost of handling silage has resulted on many farms in the practice of self-feeding.

There are no particular difficulties in self feeding but its successful application depends in large measure, particularly with dairy cows, in making the silage with a high dry matter and an even quality throughout the silo.

TABLE 49: YIELDS OF ENERGY AND PROTEIN PER ACRE OF VARIOUS CROPS

Crop	Yield per Acre tons	S.E. lb.	P.E. lb.	D.C.P. lb.
Kale	25	5100	725	—
Mangolds	30	4290	270	—
Swedes	20	3280	314	—
Oats	1½	1666	212	—
Barley	1¼	2000	204	—
Beans	1	1478	442	—
Good meadow hay ...	2	1792	224	—
Poor meadow hay ...	2	1594	138	—
Oat and tare silage ...	10	2410	320	420
Grass and clover silage	8	2240	370	496
Dried grass	3	3471	624	—

Cropping for Stock Food—On many farms more use could be made of catch crops and forage crops. Table 50 summarises the necessary information:—

TABLE 50: CATCH AND FORAGE CROPS
(H. I. Moore)

When to to Sow	What to Sow	When Ready
February	Rye and peas	June
March	Italian ryegrass (10 lb. per acre) Trefoil (2 lb. per acre)	Autumn-spring
	Cabbages	November-March
	Kale	September-December
	Cereal-legume mixture	July-August
April	Italian ryegrass-trefoil	Autumn-spring
	Cabbages	November-March
	Kale	October-January
	Cereal-legume mixtures	July-August
	Lucerne	Autumn onwards
	Rape	6 weeks' time
	Lupins	July onwards
	Mustard	6–8 weeks' time
May	Turnips	September
	Maize	August-September
	Buckwheat	12–14 weeks' time
	Cabbage	Early spring
	Buckwheat, peas and rape	12 weeks' time
June	Turnips	September-October
	Mustard and rape	6 weeks' time
	Crimson clover	September-June
	Cabbage	Spring and summer
	Rape, kale	Spring
August	Italian ryegrass-trefoil	October-spring
	Turnips	October
	Rape and mustard	6–8 weeks after sowing
	Crimson clover	May-June
	Cabbage	Late summer
September	Italian ryegrass-trefoil	Spring
	Crimson clover	May-June
	Rye	May
	Rye and winter vetches	May
October	Winter barley	May-June
November	Wheat and winter vetches	July

PREPARATION OF FOOD STUFFS

Pulping—Unless it is the intention to persuade animals to eat very large quantities of roots it is unnecessary to pulp them except for broken mouthed sheep or when fattening pigs receive several pounds per day as in the Lehmann system of feeding.

Chaffing—It is desirable to mix some chaffed straw with the concentrate ration fed to horses. They will then chew the food properly and not bolt it. Chaffing of straw for other stock is not good practice unless done to ensure large quantities of straw are consumed. It is better to give straw long so that stock may eat the more nutritious parts and leave the woody, stemmy parts.

Cutting green crops such as kale for feeding to housed or yarded stock is a useful way of reducing wastage.

Soaking—There are several reasons why food may be soaked prior to feeding:—

(1) To reduce wastage by blowing away of food.

(2) To render dusty foods less troublesome to beasts.

(3) To reduce the risk of digestive disorders from consumption in the dry state of foods that will swell a great deal when wet.

(4) Certain foods are more palatable when soaked.

(5) Certain foods, e.g., bran, have a laxative effect when fed as a mash.

Cooking—There is no evidence that cooking of foods is necessary or desirable except as follows.

Raw potatoes may cause digestive troubles; cooking renders them much more readily digested. They should always be cooked for feeding to pigs. Cattle eat raw potatoes but only moderate amounts should be fed to young and pregnant animals. This applies also to sheep.

Swill must be boiled if for no other reason than to comply with the law. If linseed is used as a constituent in gruels then the gruel must be boiled. The use of warm water that has not boiled is very dangerous.

Crushing and Grinding—Whether foods are crushed or ground depends on the class of stock. Young calves under

six months relish whole grains and chew them well. It is usual to grind food for pigs because of the small digestive system. Grains for gruel feeding are ground. For other classes of cattle, for horses and sheep, cereals are normally crushed or rolled and beans and peas cracked. The grinding of roughages for cattle and sheep does not increase digestibility. In fact the reverse may occur. Grinding of foods to an over-floury consistency increases the pastiness to an extent that the animals dislike and reduces the palatability.

The grinding of dried grass and dried lucerne produces a valuable food for inclusion in moderate amounts in the rations of pigs and poultry.

Certain general rules of good feeding practice should be borne in mind by all whose responsibility it may be to care for livestock.

The ration as a whole must be so designed that it is suited to the digestive system of the animal eating it. Stock with large digestive systems, the horse, cattle and sheep need rather bulky rations to ensure efficient digestion and a satisfied feeling. Young animals cannot be expected to consume a great deal of bulk. Excessive feeding of bulky foods such as straw and hay to dairy cattle may produce a fall in milk yield and a watchful eye must be kept on the total dry matter and fibre content of their ration. Young stock eating excessive quantities of moderate value bulky foods such as roughages may become stunted and pot bellied. On the other hand ruminants should be encouraged to eat adequate quantities of bulky foods in order to develop a good digestive system.

Pigs need a more concentrated ration although their ability to utilise efficiently certain bulky foods such as roots is greater than was previously thought.

Feeding must be carried out with regularity. Failure to adhere to the proper times each day has an unsettling effect on animals. When animals are being hand-fed they should have at least two meals a day. Very young stock, high yielding cows and fattening cattle should be fed more frequently. Not only should the meals be regular but the quantities fed should not change from day to day. Any change in a ration either of quantity or make-up should be made gradually over a period of some days.

In addition to supplying, so far as it is possible to deter-

mine, the energy, protein, minerals and vitamins needed by the animal the ration must be palatable. It should be slightly laxative rather than costive. Mixtures of cereals and meals should be in a suitable mechanical or physical condition for the particular class of animal. Thus, crushed foods are better than ground for cattle, sheep and horses, whilst pigs are usually fed on ground meals. Foods over-mealy and over-floury become pasty when masticated and are not enjoyed. Flaky foods help to " lighten " an otherwise heavy mixture.

Adequate feeding space for each animal is most important. Considerable waste of energy results from animals struggling for feeding room. Troughs, cribs, mangers, buckets and any other feeding utensils must be cleaned frequently. With young stock particularly it is important to give only small quantities of food at a time.

Stale food that stock have mouthed over will not be eaten.

Certain foods can produce tainted milk or flesh. Milk taints may be " internal " due to a food a cow has eaten or " external " due to odour in the milking place. Cabbage, kale, rape, turnips, swedes and beet tops which can cause internal taints should be fed in moderate amounts and immediately after milking. Silage, if fed in the cowshed just prior to or during milking, may cause an external taint. In the feeding of pigs high oil content fish meal should not be fed to bacon or pork pigs though it may be used for breeding stock. Low oil content fish meal in the normal amounts may be safely used for fatteners.

All animals are individuals; this should never be forgotten. General rationing schemes may be drawn up for a group of stock but the good stockman will watch the individual and be prepared to make any necessary adjustments.

Finally, in devising rations, the cost must always be borne in mind for the cost of the food is a major part of the total production cost of all animal products.

FEEDING

A RATION is often considered as consisting of (*a*) a maintenance part and (*b*) a production part.

The amount of energy required by an animal for any particular purpose is given as Starch Equivalent (S.E.) and the protein requirement as Protein Equivalent (P.E.).

The Table 51 summarises energy and protein requirements for different types of livestock.

TABLE 51: MAINTENANCE STANDARDS (AMOUNTS PER DAY)

CATTLE Live Weight	S.E. (Starch Equivalent)	P.E. (Protein Equivalent)
lb.	lb.	lb.
100	1·07	0·11
200	1·79	0·18
300	2·43	0·24
400	3·01	0·30
500	3·57	0·36
600	4·08	0·41
800	5·07	0·51
1,000	6·00	0·60
1,100	6·44	0·65
1,200	6·87	0·69
1,300	7·30	0·73
1,400	7·72	0·77
SHEEP Live Weight	S.E.	P.E.
lb.	lb.	lb.
60	0·73	0·08
80	0·90	0·10
100	1·07	0·12
140	1·38	0·16
160	1·52	0·17
200	1·79	0·20

HORSES

Maintenance requirements are shown as an amount of dry matter to be fed each day usually in the form of good roughage. The right-hand column gives the amounts of hay corresponding to those amounts of dry matter in the centre column.

Live Weight	Dry Matter	Hay
cwt.	lb.	lb.
6	9	10½
10	13	15½
12	14¾	17½
14	16¼	19
15	17	20
16	17¾	21
18	19¼	22½

Production Requirements—Animal production may be growth, fat, milk, work, wool, foetal development.

The energy (S.E.) and protein (P.E.) required for production is the production requirement, and the production ration is that amount of food which, fed in addition to the maintenance ration, supplies these requirements. The division of a day's food into maintenance and production portions is rather an artificial conception.

TABLE 52: COWS—MILK PRODUCTION REQUIREMENTS PER GALLON

Butter Fat	S.E.	P.E.
per cent.	lb.	lb.
3·5	2·4	0·52
3·75	2·5	0·55
4·00	2·6	0·58
4·25	2·7	0·61
4·50	2·8	0·63
4·75	2·9	0·66
5·00	3·0	0·69
5·25	3·1	0·72

Cattle—Growth—The table below applies to heifers and steers where the former are dairy herd replacements and the latter not to be fattened until mature. If the steers are required to fatten at an earlier age then a more generous allowance should be made to allow for a gain of rather more than 1 lb. per day.

TABLE 53: AMOUNTS PER DAY

Live Weight	S.E. per 1 lb. L.W.G.
lb.	lb.
200–400	1·50–1·75
400–600	1·75–2·00
600–800	2·00–2·50
800–1000	2·50

The protein needs of growing cattle may be shown as a suitable S.E. : P.E. ratio at various weights:—

	Ratio S.E. : P.E.
Up to 200 lb. live weight	5 : 1
At about 350 lb. ,, ,, ...	6 : 1
At about 600 lb. ,, ,, ...	7 : 1
At about 700 lb. and over ,, ,, ...	8 : 1

Cattle—Fattening—With a well-grown store beast where little growth is required the amount of S.E. needed per day to produce each 1 lb. of live weight gain is as follows:

In early fattening stage	2¼–2½ lb. S.E.
In middle fattening stage	3 lb. S.E.
In final fattening stage	3¾–4 lb. S.E.

The ratio of S.E. : P.E. in the *whole* ration should be approximately 8 : 1. Thus the actual protein supplied each day will vary from approximately 1·3 lb. to 1·7 lb. with a probable average in the fattening period of 1·5 lb. P.E.

Steaming up dairy cows and heifers—The expression steaming up refers to the additional food fed to an in-calf heifer or cow during the six to eight weeks before parturition. Commonly the animal will be given at the start of the period 1–4 lb. per day of meal or concentrate mixture balanced for milk production or its equivalent in some other food. The quantity is steadily increased according to condition and anticipated peak yield after calving, up to the amount shown below. The maximum rate is reached 7–10 days before calving.

Condition of cow at start of steaming up	Probable peak yield per day Gallons		
	4	6	8
	Maximum amounts of concentrates fed per day during steaming up lb.		
Good	4	8	12
Lean	8	12	16

SHEEP

Ewes' milk production—There is little authentic knowledge regarding the milk yield of ewes of different breeds. An average yield of three gallons per week is often assumed.

As ewes' milk is richer than cows' in both fat and protein it is necessary to supply more energy and protein per gallon than is given to lactating cows.

An adequate theoretical allowance is 3 lb. S.E. and 1 lb. P.E. per gallon per week in addition to the maintenance ration. Not many flock owners feed as generously as this in practice. A more usual rate of protein feed is a total of 3 lb. P.E. each week.

Fattening—Many sheep will be growing and fattening at the same time. The following table gives the amount of S.E. required for each 1 lb. live weight gain in respect of sheep of various live weights.

Live Weight	S.E. per 1 lb. L.W.G.
lb.	lb.
60	1½
80	1½
100	2
120	2½
140	3

The ratio of S.E. : P.E. in the whole ration should be 6 : 1 or 7 : 1.

HORSES

Production needs are related to type and speed of work, which is usually classified as light, medium and heavy. Light work at speed is regarded as medium and so on. In practice requirements are usually shown as pounds of oats per day.

WORK PRODUCTION OF HORSE

	lb. D.M. additional to M.R. per day	lb. of Oats per day
Light work ...	6	7
Medium work ...	9½	11
Heavy work ...	14½	16½

Part of the oat ration may be replaced by other foods as shown below:—

			lb.
Oats 10 lb.	=	Maize	7·7
		Barley	8·4
		Beans	9·0
		Swedes	90·0
		Mangolds	90·0
		Bran	13·2

PIGS

The rate of growth of pigs is so rapid that it is not usual to express their needs in the form of maintenance and production. The starch equivalent of good pig meals is within the range of 67–70 and this together with the fact that the appetite of pigs of different live weights is reasonably well known, enables their needs to be stated in lb. of meal per day with a S.E. of 67–70. The protein requirement is usually given either as a percentage of P.E. in the ration or as a suitable S.E. : P.E. ratio.

TABLE 54: ENERGY AND PROTEIN REQUIREMENTS OF GROWING AND FATTENING BACON PIGS

Live Weight	Meal Daily	P.E. Approx.	Approx. S.E. : P.E. ratio	Maximum Oil
lb.	lb.	per cent.		per cent.
30	1·5	13–14	4–5 : 1	4
50	2·5	13–14		4
60	3·0	12		4
80	3·5	12	5–6 : 1	4
100	4·0	12		4
120	4·5	11		4
140	5·0	11	6–7 : 1	4
160	5·5	9		4
180	6·0	9	7–8 : 1	4
200	6·0	9		4

Pork pigs can be fed on a slightly more generous scale:—

80 lb. live weight ... ... 4 lb. meal per day.
100 lb. " " ... ... 4½ lb. " "
140 lb. " " ... ... 5¼ lb. " "

Suckling Sows and Gilts—Give a daily maximum ration of 2–3 lb. meal or meal equivalent plus 1 lb. for each piglet. Thus a sow suckling 10 piglets receives 12–13 lb. meal daily. S.E. of meal approximately 65–70 per cent. and P.E. 13–14 per cent.

Pregnant Sows—Give 1 lb. meal or meal equivalent for each 100 lb. live weight plus any addition needed to improve condition after weaning or later to allow for growth of pigs in utero and build up of udder. Thus a 350 lb. sow could

receive 5 lb. meal per day after weaning and 6–7 lb. per day during the last month of pregnancy. S.E. of meal 65–70 per cent., P.E. 12–13 per cent.

In these cases adjust the P.E. of meal according to the nature of any bulky food fed.

Stock Boars—Require 4–7 lb. of meal or meal equivalent daily according to size, condition and frequency of service.

DRY MATTER APPETITE

The dry matter appetite is not a fixed amount. It varies with class of stock, with individuality, with type of ration fed and level of productivity of the animal.

Cattle—The general guide is to allow $2\frac{1}{2}$ lb. dry matter each day per 100 lb. body weight. High yielding cows may eat 3 lb. or a little more, beef beasts may not eat quite so much ($2\frac{1}{4}$ lb.) whilst very young ruminants also eat less.

Sheep—A general amount is $2\frac{1}{2}$ to 3 lb. of dry matter for each 100 lb. live weight although lactating ewes may have much bigger appetites.

Horses—When doing light work the appetite is about 2 lb. dry matter for 100 lb. live weight increasing to $2\frac{1}{2}$ lb. with more severe work.

Pigs—The appetite of the pig has been clearly shown in the feeding table on page 392.

WATER REQUIREMENTS

Supplies are often inadequate, given irregularly and frequently far from clean. A bad supply is a frequent source of trouble.

Part of the animal's need is supplied in the food eaten; the greater the succulence of the diet the less water required. Whilst *ad lib.* supplies are best the following daily quantities are a guide:—

In pig sows	At least 1 gallon.
Suckling sows ...	Up to 4–5 gallons.
Fattening pigs ...	In early stages 3 lb. water per 1 lb. meal.
	In later stages $1\frac{1}{2}$–$1\frac{3}{4}$ lb. water per 1 lb. meal.
Horse	8–10 gallons.

Sheep ... ... Contrary to many opinions sheep make use of water supplies even when grazing succulent pasture.

Fattening cattle ... 6–7 gallons in winter.
7–8 gallons in summer.

Milking cows ... A basic supply of 7–10 lb. of water per 100 lb. live weight plus 10–15 lb. per gallon for the first two gallons and 15–20 lb. per gallon for the remaining milk yielded.

MAKING UP RATIONS

The examples that follow show how to work out rations for different groups of stock and suggest certain rationing schemes based on the feeding standards given earlier on.

Each animal is an individual and a ration suiting one beast may fail to produce satisfactory results with another. Careful and skilled observation of animals is of fundamental importance. Moreover, farming is a business and it is essential to pay regard to feeding costs and make use of foods that supply energy and protein at the cheapest cost per unit.

HORSES

Alternative daily rations for a farm horse weighing about 15 cwt.

Food	Light Work lb.		Medium Work lb.		Heavy Work lb.	
	1	2	1	2	1	2
Hay	20	17	20	20	20	20
Oats ...	7	5	11	5	16½	10
Beans ...	—	—	—	1¾	—	3
Bran ...	—	—	—	—	—	3
Barley ...	—	1¾	—	3½	—	—
Swedes ...	—	14	—	—	—	—

PIGS

Suckling Sows—Ration for sow suckling 10 piglets. Daily requirement is 12–13 lb. meal with a Starch Equivalent 65–70 per cent. and Protein Equivalent of 13–14 per cent.

	per cent.	S.E. (lb.)	P.E. (lb.)
Flaked Maize	10	8·4	0·92
Barley Meal	50	35·7	3·65
Weatings	20	11·0	2·00
Bean Meal	10	6·6	1·97
White Fish Meal ...	10	5·9	5·30
		67·6	13·84

or

	per cent.	S.E. (lb.)	P.E. (lb.)
Barley Meal	30	21·42	2·19
Oats	15	9·00	1·14
Weatings	20	11·00	2·00
Meat and Bone Meal ...	12½	8·40	4·30
White Fish Meal ...	2½	1·47	1·42
Wheat Meal	20	14·32	1·92
		65·61	12·97

Bacon Pigs—A typical feeding scheme that recognises the decreasing need for protein, and particularly animal protein, as fattening proceeds is as follows:—

Food	Meal No.			
	1	2	3	4
	per cent.	per cent.	per cent.	per cent.
Barley Meal	37½	50	65	60
Oats	—	—	—	15
Maize Meal	15	—	—	—
Flaked Maize	20	10	—	—
Weatings	15	25	25	20
White Fish Meal ...	12½	2½	—	—
Meat and Bone Meal ...	—	12½	5	—
Decorticated Ground-nut Meal	—	—	5	5
S.E. of Mixtures ...	72·09	67·72	67·26	66·44
P.E. of Mixtures ...	14·13	12·81	11·00	9·62
Minerals	—	—	1	2

Meal 1. 3 weeks old to approximately 50 lb. live weight.
„ 2. 50 lb.–100 lb. live weight.
„ 3. 100 lb.–150 lb. live weight.
„ 4. 150 lb.–slaughter.

Meals such as these can be fed with water or whey. One gallon whey replaces approximately ¾ lb. of meal.

To make systematic use of bulky foods the Lehmann system of pig feeding was devised. Pigs receive an all meal ration until 50–60 lb., in some cases 80–90 lb., live weight. Bulk food is then introduced and whilst the amount of meal fed daily remains constant the quantity of bulk food gradually increases. As most bulky foods, for example, potatoes, fodder beet, are low in both protein and minerals, the meal mixture has to be reasonably high in protein (13–14 per cent.) and reinforced with minerals. A mixture containing 10 per cent. fish meal or its equivalent is satisfactory. A suitable mineral mixture is:—

Feeding Bone Flour ...	...	1 part by weight.
Ground Chalk ...	...	1 „ „
Common Salt ...	...	½ „ „

Feed 2½ lb. to each 100 lb. of meal.

The following table illustrates the method where the potatoes are introduced "A" about 50–60 lb. live weight, and "B" about 80 lb. live weight.

Live Weight lb.	SCHEME A		SCHEME B	
	Meal per day lb.	Potatoes per day lb.	Meal per day lb.	Potatoes per day lb.
50	2½	—	2½	—
80	2½	4	3½	introduce
100	2½	6	3	4
120	2½	8	3	6
160	2½	12	3	10
180	2½	14	3	12
200	2½	14	3	12

SHEEP

Teg fattening in winter—Required to gain 2 lb. per week from a starting live weight of 80 lb.

Nutritive Requirements

	Live Weight lb.)		
	80	100	120
Maintenance Ration (S.E.) lb./week	6·5	7·5	8·5
Production Ration (S.E.) lb./week	3·5	4·0	5·0
Total S.E.	10·0	11·5	13·5
Total P.E.	1·5	1·7	1·9

Rations fed. Amounts in lb. per week.

Food	Live Weight (lb.)		
	80	100	120
	lb.	lb.	lb.
Kale	90	90	100
Hay (good meadow) ...	5	5	5
Cereals	—	2	4
S.E. supplied	10·0	11·4	13·5
D.M. supplied	16·8	18·5	20·0

At the lower live weights the amount of P.E. in the ration is only just adequate.

Many farmers economise by not feeding any cereals or concentrates but accepting slightly slower rates of live weight gain.

A ration of:—

Kale and Swedes ... ... 130 lb. per week.
Hay ... ... 2–3 lb. per week.

for instance, provides approximately 12 lb. S.E. and 1½ lb. P.E. each week.

Ewe suckling lambs—It is assumed that pasture is not available.

Live weight of ewe		150 lb.
Maintenance Ration (S.E.) per week	=	10 lb.
Production Ration (S.E.) per week	=	9–12 lb.
Total P.E. per week	=	3 lb.

Ration per week—

	S.E. (lb.)	P.E. (lb.)
Kale, 140 lb.	14·42	1·96
Hay (good meadow), 7 lb. ...	2·66	0·31
Concentrates, 8 lb.	4·50	0·76
	21·58	3·03

The concentrate mixture is:—

Crushed Oats	60 per cent.
Barley	30 " "
Decorticated Groundnut Cake ...	10 " "

REARING CATTLE

All calves should receive their dam's colostrum during the first one to four days after birth.

Calves may be reared in one of the following ways:—

Natural—The cow suckles her own calf usually for four to six months. It is the normal method on rearing farms and in beef breeding herds. Cows normally calve April—May.

Foster Mother System—A cow suckles several calves each lactation. The number depends on the yield of the cow and the amount of milk allowed each calf. When practised intensively the method needs careful supervision.

Example 1

1st calf suckles	1st–13th week.
2nd calf suckles	1st–14th week.
3rd calf suckles	3rd–17th week.
4th calf suckles	14th–27th week.
5th calf suckles	15th–28th week.
6th calf suckles	18th–31st week.
7th calf suckles	28th–41st week.
8th calf suckles	32nd–45th week.

Example 2. (From "The Calf," J. H. B. Roy.)

Using a cow yielding 600 gallons in the lactation.

Week of Lactation	Introduce	Wean
1	Calf I	
2	Calf II	
3	Calf III	
11	Calf IV	Calf I
12		
13	Calf V	Calf II
14		
15		Calf III
24	Calf VI	Calf IV
25		
26		Calf V
28		
38		Calf VI
39		
42		

Calves are given hay from 2nd to 3rd week and concentrates from 3rd week of age.

Generally calves will receive 1–1½ gallons of milk daily.

Artificial or Pail Feeding—The calf is removed from her dam either immediately after birth or after having suckled for 3–4 days.

Economy in the quantity of whole milk used is possible and substitutes may be separated milk, whey, gruels, reconstituted milk powder. Alternatively moderate amounts of whole milk may be fed and the calf weaned on to concentrates (follow on type) and hay.

Whichever method is used the live weight gain wished for in the case of dairy heifer calves is likely to be as under during the first six months.

Jersey and Guernsey calves ...	1·0 lb. per day.
Ayrshire	1¼–1⅓ lb. per day.
Friesians	1½ lb. per day.
South Devons	1½ lb. per day.

The following approximate 180 day live weights would then be anticipated.

Jersey	approximately	240 lb.
Guernsey	,, ...	270 lb.
Ayrshire	,, ...	290 lb.
Friesian	,, ...	360 lb.
South Devon	,, ...	370 lb.

When calves are reared for beef or veal production or as bulls then faster rates of gain, at least 2 lb. per day are essential.

Before giving details of certain alternative methods of rearing artificially the following general notes are given.

1. Feed calves at least three times daily for the first three weeks, feed at the same times each day and space the feeds as evenly as is possible.

2. Dilute the milk from Channel Island and South Devon cows. This may be done with water (dilution rate of 25 per cent.) or preferably with separated milk by adding one quart of the separated to two quarts of whole milk. Certain authorities recommend some dilution of the milk of all breeds in order to produce a softer curd in calves' stomachs.

3. Feed milk at a temperature of 95–100° F. during the first several weeks of life. After that it is less important to do so but a change from warm milk to cold milk must be gradual.

4. If digestive troubles occur stop milk feeding, give an aperient, give clean water for 24 hours and then re-introduce milk gradually.

5. Utensils used for milk or gruel feeding should be properly cleaned and sterilised after each meal.

6. Water is not really essential during the first two or three weeks of life but after that should be available all the time.

7. Feed only good quality hay and encourage calves to eat it as soon as possible. Hay nets are useful in reducing waste of hay.

8. Green food is a valuable addition to the diet and may replace some of the hay after calves are 6–8 weeks old.

9. Roots are less useful being lower in protein, minerals and vitamins.

10. Good quality silage may be fed as calves approach 3 months of age.

11. Individual pens are best for calves before they are weaned from whole milk or liquid substitutes.

Example of daily food consumption of heifer calves of different breeds at 12 weeks of age (after weaning).

Breed	Hay lb.	Concentrates lb.
Jersey	2½–3	2¼–2½
Guernsey	3	2½–3
Ayrshire	3–3½	3
Dairy Shorthorn ...	3½–4	3–3½
Friesian	4½–5	3½–4
South Devon	5½–6	4

PAIL FEEDING METHODS

1. Whole milk (diluted when necessary). Calves weaned on to hay and concentrates.

Weeks 1–3 *inclusive*:

Increase daily milk feed so that by 21 days old:—

Jersey calves are receiving ...	6 pints per day.
Guernseys and Ayrshires ...	8 pints per day.
Dairy Shorthorns	10 pints per day.
Friesians	12 pints per day.
South Devons	14 pints per day.

If separated milk is used to dilute milk then feed one pint separated and two pints whole milk, thus a Friesian would receive four pints separated and eight pints whole at three weeks.

If water is used to dilute add 20–25 per cent. of water to above quantities.

Maintain maximum rate of milk feed for two more weeks and then gradually reduce to nil at end of 12th week of age. For example:—

	Pints of Milk per day at		
	8th week	10th week	12th week
Guernsey ...	6	4	2
Friesian ...	8	4	2
South Devon	10	6	2

Weaning can be earlier than the 12th week, e.g., at 8 weeks of age if calves are eating adequate solid food. Introduce

DAILY AMOUNTS FED

Week	Milk Pints	Separated Milk Pints	Hay	Balancer Meal lb.	Follow on Meal lb.
1	6	—	—	—	—
2	7	—	Introduce at	—	—
3	8	Introduce	2–3rd week	From 3rd	—
4	—	10	and increase	week give	—
6	—	12	to appetite	1 lb. per	—
[illegible]	—	12	—	gallon	Introduce at
10	—	12	—	separated	10–12th week
12	—	12	—	milk	and increase to
14	—	8	—	—	4 lb. at 16th
16	—	Wean	—	—	week

good hay and concentrates as calves approach three weeks of age and steadily increase amounts.

A general formulae for the concentrate mixtures—often referred to as a " follow on " mixture is:—

	Total per cent.	Digestible per cent.
Protein	22–25	17–21
Oil	5–7	4–6½
Fibre	5–7	
Carbohydrate	44–48	
Lime	1–1·5	
Phosphoric Acid ...	1·5–1·8	
Starch Equivalent ...	70–74	

Most suitable mixtures will contain 10 per cent. of White Fish Meal or another animal protein, linseed cake 30 per cent. and mixed cereals 60 per cent.

Examples are:—

Food	MIXTURE 1	2	3	4
	per cent.	per cent.	per cent.	per cent.
Crushed Oats	40	20	35	40
Linseed Cake	30	40	17½	20
Flaked Maize	20	20	17½	20
Beans	—	—	—	10
White Fish Meal ...	10	10	10	10
Coarse Middlings ...	—	10	—	—
Bran	—	—	10	—
Ground Linseed ...	—	—	10	—

2. Whole Milk and Separated Milk—Separated milk is lower in energy value than whole milk hence it is necessary to use a balancer food high in Starch Equivalent. Cereal mixtures are adequate. As the amount of separated milk is reduced the balancer meal is replaced by normal " follow on " concentrates.

Weaning may be as early as the 12th week providing calves are eating adequate amounts of hay and balanced concentrates. With earlier weaning concentrates would be fed at an earlier age than is shown in the table opposite.

3. Whole Milk, Milk Replacement with Calf weaned on to Hay and Concentrates—Whole milk is fed only for a few days or sometimes for the first three weeks. It is replaced over a period of several days by milk replacement which is reconstituted with water. The amount of replacement given is usually the same as the amount of whole milk that would otherwise have been fed.

Hay and concentrates are introduced at the usual age and the calf weaned between eight and twelve weeks of age.

4. Whole Milk and Gruel—Whole milk is replaced by gruel during the 3rd to 5th week and the gruel finally stopped at about the 10th to 12th week. The whole milk need not exceed 20–25 gallons. Gruels need care in preparation and the Ministry of Agriculture consider that they should have the following general food value; protein 20–24 per cent., oil 4½–7 per cent., fibre not to exceed 5 per cent. 1 lb. of gruel is usually added to 10 lb. water. If gruels contain linseed they must be boiled for at least 5 minutes. Hay and "follow on" concentrates are introduced at the 2nd to 3rd week. Examples of gruel mixtures are:—(From *The Calf*, by J. H. B. Roy.)

	Parts by Weight 1	2	3
Ground Oats...	2½	4	1
Middlings	2½	–	1
Maize Meal	2½	–	–
Linseed Cake Meal	1½	4	3

5. Weaning on to Pasture—In summer it is possible to wean calves on to pasture when they are 7–8 weeks old. Calves receive milk only for three weeks and then go out to graze young leafy grass. The amount of milk fed is steadily reduced and none is fed after the 8th week, as is shown in the table.

The Ayrshire receives about 40 gallons and the Friesian about 50 gallons.

Calves require a continual supply of leafy young pasture, they should be moved frequently.

Concentrates are not fed but some hay or really good quality straw should be put in racks in the field so that they may help themselves.

	Pints per day	
	Ayrshire	Friesian
By end of 3rd week ...	8	12
During 4th week ...	8	12
During 5th week ...	7	10
During 6th week	5	7
During 7th week ...	4	4
During 8th week ...	2	2

In early summer some straw bales can provide a little shelter and in the heat of the summer they may need a shelter from the sun.

MISCELLANEOUS

1. If navel cord does not rupture naturally sever it about 4 in. from calf using sterilised scissors.
2. If navel cord is dressed tie a thin string soaked in disinfectant round the cord about 1 in. from the body, and apply bluestone, or tincture of iodine or lysol.
3. Bull calves for rearing for beef should be castrated not later than three months of age.
4. Dehorning should be done during the first few days after birth. If collodion is used the day after birth is probably better than later.
5. Extra teats may be cut off with sterilised scissors when the calf is 3–4 weeks old. Disinfect that part of the udder before the operation.
6. Vaccinate calves with S.19 when they are 4–6 months old.

DAIRY HEIFERS

Generally calves are not turned out to pasture until 5–6 months of age. During the first summer they should graze clean pasture—preferably leys that have not been grazed by older cattle previously. They should not graze with or immediately after older cattle. Calves housed during the summer benefit from fresh cut green food. Heifers are often housed again at about a year old but older heifers can winter outside.

Some alternative rations:—

	Live Weight (lb.)							
	600				800			
	1	2	3	4	1	2	3	4
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Grass Silage ...	30	30	—	—	40	30	40	—
Kale ...	25–30	—	30	—	—	—	25–30	—
Meadow Hay (good quality)	—	7	10	10	7	10	—	10
Mangold	—	—	—	20	—	—	—	40
Oats ...	—	—	—	1	—	—	—	1
Beans	—	—	—	1	—	—	—	1

Ration number 4 in each case may be a little low in protein, and may be improved by an additional ½ lb. beans or some equivalent food.

RATIONS FOR DAIRY HEIFERS

Aged 6 months. Live weight 330–340 lb.

S.E. for maintenance	=	2·70 lb.	
S.E. for $1\frac{1}{3}$ lb. L.W.G. daily	=	2·00 lb.	
Total	=	4·70 lb.	
P.E. at $\frac{1}{6}$		0·78 lb.	

Feed daily:—	S.E. lb.	P.E. lb.
Hay, 5 lb.	1·90	0·20
Kale, 10 lb.	0·91	0·13
Concentrates, 3 lb.	1·90	0·46
	4·71	0·79

Concentrate Mixture:—

Oats	60 per cent.
Barley	20 „
Fish Meal	10 „
Decorticated Groundnut Cake ...	10 „

Rations for older heifers weighing (*a*) 600 lb.
(*b*) 800 lb.

to gain approximately 1 lb. daily.

	Live weight (lb.) 600	800
S.E. (lb.) for maintenance ...	4·1	5·0
S.E. (lb.) for growth	2·0	2·5
	6·1	7·5
Total P.E. (lb.)	0·87	1·0

Rations for Steers to be fattened when mature.
Rates of gain anticipated = $1\frac{1}{2}$ lb. per day.

	Live weight (lb.)	
	400	600
S.E. (lb.) for maintenance ...	3·0	4·1
S.E. (lb.) for growth ...	2·2	3·0
Total S.E. (lb.) ...	5·2	7·1
Total P.E. (lb.) ...	0·9	1·0

Some Alternative Rations.

	Live Weight (lb.)					
	400			600		
	1	2	3	1	2	3
	lb.	lb.	lb.	lb.	lb.	lb.
Hay	5	5	5	10	—	6
Grass Silage ...	10	—	—	25–30	30	30
Kale	—	10	—	—	30	—
Mangold	—	—	10	—	—	20
Straw	—	—	—	—	3–4	—
Concentrate Mixture	(1) 3	(1) 3¾	(2) 4			

(1) = A mixture with S.E. 68 per cent. P.E. 15 per cent.
(2) = A mixture with S.E. 62 per cent. P.E. 16–17 per cent.

FATTENING CATTLE

A steer in winter starting the feeding period at 9 cwt. and selling at 11½ cwt.

DAILY RATION

Foods	Early Stage	Middle Stage	Final Stage
	lb.	lb.	lb.
Swedes	52	—	—
Mangold	—	60	60
Hay	10–11	14	14
Oat Straw	6	—	—
Oats	2¼	3¼	5½
Mixed Cake and Meal	3½–4	3½–4	3½–4

Composition of mixture—

Either:—Decorticated Groundnut Cake ... 1 part.
Oats or Barley ... ... 2 ,,
Flaked Maize ... ... 1 ,,

or:— Equal parts of oats and beans fed at 4 lb. per day.

Liberal feeding of concentrates is too expensive and the following scheme shows how to use bulk foods as replacements.

Fattening steers without concentrates—

Starting weight approximately 1000 lb.—selling weight approximately 1300 lb.

Daily Rations:—

Foods	Early Stage	Middle Stage	Final Stage
	lb.	lb.	lb.
Grass Silage	70	80	100
Hay	6	7	6–7

or for a rather smaller steer gaining at approximately 2 lb. per day.

Daily Rations:—

	Live weight (lb.)		
	950	1050	1150
	lb.	lb.	lb.
Grass Silage	60	60	60
Hay	7	7	7
Oats	2	4	6

DAIRY CATTLE

In the production of winter milk concentrates should be used only for cows whose high yield justifies the expenditure.

Rations for a 9 cwt. cow at various yield levels—

Food	DAILY YIELD (GALLONS) 1			2			3			4		
	RATIONS 1	2	3	1	2	3	1	2	3	1	2	3
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Hay	—	3	10	3	—	14	7	—	7	7	7	7
Grass Silage	30	20	—	40	50	50	40	50	20	20	40	60
Kale	56	56	56	56	56	—	56	56	56	56	56	—
Concentrate Mixture*	—	—	—	—	—	—	2	4	6	10	6	10

* S.E. = 62 per cent, P.E. = 14 per cent,

Rations for cows weighing approximately 11 cwt. at various yield levels.

DAILY YIELD (GALLONS)

	1					2				3				4			
Ration No.	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4
Food	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Grass Silage	—	20	40	80	25	20	40	45	20	20	40	45	90	20	40	45/50	90
Hay	14	7	—	—	10	14	7	—	10	14	7	—	—	14	7	—	—
Kale	50	50	50	—	—	50	50	70	—	50	50	70	—	50	50	70	—
Mangold	—	—	—	—	40	—	—	—	40	—	—	—	—	—	—	—	—
Cereals	—	—	—	—	—	—	—	—	—	—	—	3½	5	—	—	3	5
Concentrates*	—	—	—	—	—	—	—	—	5	4	4	—	—	8	8	4	4
D.M. approximately ...	19	17	15	16	19	24	21	20	22½	26½	24½	22½	22½	30	28	26	26

* Concentrate mixture has a S.E. 62 per cent. and P.E. 14 per cent.

The cheapest foods are silage, kale and hay and the greatest use should be made of these.

Whilst the dry matter appetite increases to some extent with yield it is necessary to exercise some degree of bulk control with higher yielders particularly with smaller breeds yielding milk rich in butter fat.

Rations of High Yielding Cows—The following table based on the method suggested by R. Boutflour gives a method of controlling the quantity of bulk or dry matter and crude fibre in the ration of high yielding cows.

The table applies to cows weighing 11 cwt.

DAILY YIELD (GALLONS)

Food	1	2	3	4	5	6	7	8
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Hay	17	17	17	15	14	12	9	6
Grass Silage	20	40	40	40	40	40	40	40
Concentrates ...	—	—	3½	7	10½	14	17½	21

GROUPING OF FOODS

For easier making up of milk production rations (Boutflour)—

GROUP I

(Foods already balanced for milk production)

Compound cakes.
National dairy cake No. 1.
Palm kernel cake or meal.
Coconut cake.
Weatings.
Bran.
Dried brewers' grains.
Dried grass (over 14 per cent. protein).
Dredge corn with at least 30 per cent. peas and/or beans.

GROUP II

(Mix 1 part with 1 part of any food in Group VI)

National dairy cake No. 2.
Linseed cake.
Peas and beans.
Distillers' dried grains.
Maize gluten feed.
Malt culms.
Undecorticated cotton cake.
Sunflower seed cake.

GROUP III

(Mix 1 part with 2 parts of any food in Group VI)

Undecorticated groundnut cake.

Maize gluten meal.

National grain balancer (cake or meal).

GROUP IV

(Mix 1 part with 3 parts of any food in Group VI)

National high protein cake or meal.

Decorticated groundnut cake or meal.

Decorticated cotton seed cake or meal.

Soya bean cake or meal.

GROUP V

(Mix 1 part with 5 parts of any food in Group VI)

White fish meal.

Dried yeast (in limited quantities only).

GROUP VI

(Cereal Foods)

Maize meal.

Maize germ meal.

Crushed wheat, rye, barley or oats.

Dredge corn with less than 30 per cent. peas and/or beans.

Flaked maize.

Locust beans.

Tapioca meal.

Dried sugar beet pulp.

Molasses.

Dried potato products.

For high-yielding cows and for Channel Island cattle more concentrated mixtures will often be necessary.

For example, the following mixture may be fed at 2·6 lb. per gallon of 3·75 per cent. B.F. milk or at 3¼ lb. per gallon of 5 per cent. B.F. milk.

Linseed	300 lb.
Flaked maize	300 lb.
Fish meal	100 lb.

It has a S.E. of 95 per cent. and P.E. of 19 per cent.

This mixture may be fed at 4 lb. per gallon of 5 per cent. B.F. milk and at 3⅓ lb. per gallon 3·75 per cent. B.F. milk.

Wheat	20	per cent.
Barley	20	,,
Decorticated groundnut cake ...	25	,,
Palm kernel cake	10	,,
Flaked maize	25	,,

S.E. = 75 per cent., P.E. = 17¾ per cent.

ANIMAL HEALTH

GOOD management is the best aid to health. Ill-health often follows cold, damp housing, overcrowding (indoors or on pasture), and digestive disorders, especially in young animals. Stress of any kind is weakening, e.g., calving, sudden change of environment, etc.

HYGIENE

Cleanliness and disinfection of the premises and equipment, and the disposal of manure to avoid contamination of water, or fields used by young stock, are important in preventing spread of diseases. Knives or intruments used for castration, etc., should be sterilised between each operation. Rats commonly spread disease and should be destroyed. Personal hygiene is important; after attending to any sick animal, workers should thoroughly wash and scrub the hands in weak disinfectant, then soap and water.

Isolation of sick animals, either individually or in small groups, avoids spread of infection.

Quarantine of incoming stock, animals or birds, for at least 30 days, reduces risks of introducing infection by apparently healthy carrier animals.

Modern treatments are effective if applied early; a rise in animal's rectal temperature is often the first indication of illness. However, some bacteria can become resistant, e.g., to antibiotics previously used successfully.

Correct diagnosis is essential to aid correct choice of preventive inoculations or medicines. This may need laboratory tests of suitable specimens, e.g., milk in mastitis; or faeces for intestinal worm infestations; blood samples in contagious abortion. Some tests can reveal unsuspected disease before symptoms are shown, e.g., tuberculin tests.

Preventive inoculations, when available, offer cheap insurance against certain diseases, e.g., pulpy kidney disease, swine fever, brucellosis, louping ill. Antiserum gives immediate but short-lived protection (four to eight weeks),

whilst vaccine is slower acting but produces longer immunity (perhaps six to twelve months). All treatments should be applied in right dosage at the right time.

NOTIFIABLE (SCHEDULED) DISEASES

Every person in charge of an animal or carcase suspected of being affected with contagious disease is legally required to report immediately to the local Police Officer. This obligation is also imposed on any Veterinary Surgeon who encounters such a case. The suspected animal must be kept isolated pending the visit of the Veterinary Inspector. Quite apart from any penalty for failing to report, it is in the farmer's own interest to do so; timely intervention saves valuable animals and prevents further spread of disease.

Notifiable diseases now eradicated from Great Britain are Cattle Plague (Rinderpest), Glanders (Farcy), Epizootic Lymphangitis, Contagious Bovine Pleuro-pneumonia, Sheep Pox, Rabies, Parasitic Mange of Equines.

Notifiable diseases which still occur in the British Isles are Anthrax, Foot and Mouth Disease, Swine Fever, Atrophic Rhinitis, Bovine Tuberculosis (certain forms), Sheep Scab (eradicated from *England*). Fowl Pest (including Fowl Cholera) is notifiable to the local Police Officer.

Anthrax (Scheduled)—Anthrax bacilli can affect humans (causing malignant pustules and wool-sorters' disease) and all animals, and is world-wide. Bacterial spores live in soil for many years. In Great Britain it occurs in cattle and pigs, rarely in horses and sheep. It is more prevalent in tropical countries. Human workers in tanneries, knackeries, bone-processing and wool-sorting factories, are more liable to infection; contact with infected material should be reported to the Medical Officer of Health.

Origin—Animal discharges, animal products (meat and bonemeal, etc.), cattle cake, knackers' dry meat, tannery effluent, flies.

Infection enters by contaminated food, inhalation of spores in dust, skin wounds, perhaps also by biting or blood-sucking insects.

Symptoms—Often none are seen; animal is found dead, sometimes bleeding from nose, mouth or anus. Otherwise there is high fever, perhaps diarrhoea; throat swellings in

pigs and horses; death in 24–48 hours. Eighty to 100 per cent. of affected stock die, but usually only isolated cases occur. Carcase blood is tarry (non-clotting) and the spleen enlarged. A milder form causes only temporary fever and perhaps fall in milk yield.

Control—Suspect this disease in any animal which dies suddenly. Do not move or cut the carcase but cover it with sacks soaked in disinfectant and fence it off. Remove other healthy animals in contact and isolate in a separate place. Do not move ailing animals. Blood splashes and other discharges should also be soaked in disinfectant. Veterinary advice should be followed in detail.

Treatment—Less acute cases respond to penicillin injections. Vaccine and serum are used as protective measures in localised areas when Anthrax is more prevalent.

Foot and Mouth Disease (Scheduled)—Caused by four main types of virus, with other sub-types, which are resistant to cold (e.g., survive in chilled meat). World-wide, in Great Britain it chiefly affects cattle and pigs, but other cloven-hooved stock are susceptible. In some instances, migrating birds probably carry infection to Great Britain from Northern Europe.

Symptoms—Shown 12 hours to 12 days after infection, but then develop rapidly with fever, lameness, smacking of lips and drooling of saliva. Cattle exhibit blisters inside the lips, on the tongue, between the " claws " of the feet and on the teats. These burst to form ulcers; pigs may also show blisters on the body. Milk is infective before these symptoms are evident. Calves may die from bowel inflammation without showing mouth blisters. Body condition is rapidly lost and milk yield falls considerably. Death-rate is not high but recovery is so prolonged as to be uneconomic.

Control—Treatment is not permitted in Great Britain. Affected and in-contact animals are slaughtered, carcases being burned or buried, under full supervision by Government Veterinary Officers. British research workers are developing vaccines for use abroad.

Swine Fever (Scheduled)—Caused by a virus which can survive in chilled or salted carcases, but dies in 14 days in infected premises if cleared of pigs. Pigs only, of all ages, are affected. Spread by direct contact with affected pigs,

also by litter, offal, swill, utensils and contaminated boots and clothing.

Incubation—Average 6–9 days (acute), but up to 15–21 days.

Symptoms—May be indefinite, but include lack of appetite, fever (104–107° F.), shivering, and staggering gait. Sometimes there is reddish-purple rash or discoloration of the skin on ears, belly and hocks. Secondary bacteria may cause further symptoms, e.g., of scouring, or difficult breathing, etc. Death results in 30–80 per cent. cases (acute—in 3–5 days; chronic—perhaps in 3–6 weeks).

Treatment and Control—Injections of anti-serum are useful during outbreaks, but a regular vaccination programme offers more certain protection. This can be arranged through your veterinary surgeon. On suspicion of this disease, all movement of pigs from the affected farm is prohibited except by licence for immediate slaughter. Slaughter is *not* compulsory but may be the best way to eradicate the disease. The farm can be safely restocked after six weeks.

Atrophic Rhinitis (Scheduled)—No single disease agent has yet been incriminated as the cause of this disease, first noted in Great Britain in 1952.

Incubation Period—10–14 days.

Symptoms—First seen in piglets aged 2–3 weeks. Affected piglets sneeze, discharge from nose and eyes, snuffle or breathe through the mouth; 10 per cent. may die. Survivors are chronically affected, some eventually suffer progressive deformity of the snout, which becomes lopsided, with wrinkled skin. Older pigs may not show typical symptoms, nevertheless, they may be carriers of infection. Growth-rate is checked.

Spread of Infection—Often from carrier sows to their litters, and from these to in-contact litters.

Diagnosis—Based on symptoms and post-mortem examinations.

Control Measures—Isolate suspected animals. If slaughtered, compensation is paid. Treatment is not recommended; it is more economic to restart the herd with a few healthy pigs.

Tuberculosis—A contagious disease caused by tubercle bacilli, which can survive three to six months in dung, in

buildings, or on sheltered pasture, and are more resistant to chemical disinfectants than many other bacteria. Infection is spread indoors by inhalation of coughed-up sputum (" droplet infection "), on pasture by infected dung, also to humans, to calves and pigs by milk from tuberculous mastitis. Pigs are also susceptible to *avian* tuberculosis from contact with affected poultry.

Incubation Period—Very variable; it can be several months.

Symptoms—Not always characteristic. *Cattle* may develop a chronic cough and become emaciated. Tuberculous mastitis causes slow hardening, perhaps " lumpiness," in the udder; milk at first may remain normal in appearance, eventually becoming like whey, with clots. *Pigs* may show no obvious changes until slaughtered (glands in the head are often the sole organs affected).

Treatment—None. Animals suspected of spreading infection are slaughtered and compensation paid. The Tuberculosis Order (1938) requires either the owner, *or* the person in charge, of a bovine animal which shows any one or more of the above symptoms to report immediately to the local Police Officer or to a Veterinary Inspector. Also, *he is required to detain the suspect animal in isolation from other bovine animals.* Milk from this animal must not be mixed with other milk but must be boiled or otherwise sterilised. Any utensil in which such milk has been placed must be thoroughly cleansed and scalded with steam or boiling water before other milk is placed therein. N.B. All these precautions must be taken as soon as a suspect case occurs; the official notice (form A) only serves to confirm them and remains in force until the animal is slaughtered or the notice withdrawn by form B.

Control—The national scheme for eradication of bovine tuberculosis is progressing rapidly. Free tuberculin tests, slaughter of reactors, then attestation of herds freed from infection, are followed by attestation of whole counties and larger areas.

Poultry—Older hens (second and third year birds) are more commonly affected; they lose weight rapidly and pass infected droppings. Pastures and pens are left heavily infected, and should be depopulated for at least a year.

Sheep Scab (Scheduled)—Outbreaks of this disease have not occurred in England, Wales and Scotland since 1952.

It is caused by mange mites biting the skin. Highly contagious, it is spread by contact with affected animals or rubbing posts.

Incubation Period—Three weeks to six months.

Symptoms—First, restlessness occurs, with skin irritation shown by biting and rubbing of affected parts of the body. The fleece becomes ragged, skin scabs form. Small mites may be seen by examining with a magnifying glass scrapings from the edges of diseased areas.

Treatment—On instructions from Veterinary or Police Officers, sheep must be dipped in Government approved dips, viz., either arsenic preparations for "double-dipping," or in "persistent" dips such as gammexane types which require only one dipping. These dips also kill ticks, lice and keds.

Parasitic Mange (horses, mules, asses) (Scheduled)—Eradicated from Great Britain since 1948. Caused by microscopic mites irritating the skin; some types affect areas under saddles or harness, others involve either the lower limbs, or the neck, base of tail, i.e., near long hairs, but eventually spread over the whole body. Highly contagious, either by direct contact or by infected harness, grooming kit, etc.

Symptoms—Marked irritation occurs, with rubbing against anything within reach, also stamping of the feet in one form of the disease. Bare patches of skin eventually thicken and crack.

Treatment—Dipping or spraying, in dips such as gammexane preparations. Treatment, also disinfection of premises and equipment, must be carried out under supervision of Veterinary Officers.

Fowl Pest (Newcastle disease) (Scheduled)—This is a disease mainly affecting domestic poultry and caused by a virus. Infection is rapidly spread by contact with infected birds, or by contaminated poultry crates, chick and egg boxes, clothing, footwear and hands of people on infected premises.

Symptoms—Develop after an incubation period of 3–10 days. Two types of disease are known, viz., *mild type*; this has, at present, superseded the more typically fatal form of disease in Great Britain. Symptoms tend to resemble

infectious colds (nasal roup) with watery diarrhoea. As infection spreads, egg production falls rapidly. Mortality is low in adult birds, but quite high in young stock. *Acute type*—Spreads rapidly, with fall in egg production. Birds are often found dead without prior symptoms and 90–100 per cent. of a flock may die. Affected birds lose their appetite, show gasping, gurgling breathing, with discharges from mouth and nostrils, yellowish-green diarrhoea. They are sleepy, with ruffled feathers, and hide in dark corners.

Diagnosis—Based on general symptoms, post-morten examinations and blood tests.

Control Measures—In Great Britain include a policy of slaughter of affected flocks (with payment of compensation), close restriction of movement of poultry in affected areas, temporary closure of live poultry markets, and strict disinfection of vehicles and dealers' premises, poultry crates, etc., all under close veterinary supervision. All waste foods must be boiled before feeding to fowls.

Abroad, vaccination against Newcastle Disease is carried out, but is not permitted in Great Britain.

Virus Hepatitis (ducks) (Scheduled)—Not widespread in Great Britain; mainly occurs in East Anglia. Ducklings about 2 weeks old are affected; older birds develop resistance.

Symptoms—May include sudden onset of listlessness, sprawling and inability to stand and death may occur within 1–3 hours; 10–90 per cent. may die.

Control—Suspected outbreaks should be reported to the Divisional Veterinary Officer.

Those diseases now eradicated from Great Britain are unlikely to be re-established owing to strict limitations on import of animals, animal products and fodder, correct disposal of packing materials, and quarantine of certain imported stock, *but any unusual or especially virulent symptoms should always be reported to the Divisional Veterinary Officer as soon as possible.*

DISEASES TRANSMISSIBLE TO HUMANS

Certain diseases which occur in animals can also affect humans. Children are especially susceptible, but adults are not necessarily immune. Animal attendants should observe scrupulous personal hygiene, washing and disinfecting hands,

and changing outer clothing, etc., after handling sick animals. These diseases include **Brucellosis** (contagious abortion), which can cause undulant fever in man; **Bovine Tuberculosis, Anthrax,** and **Tetanus** (lockjaw); these latter bacteria are common in manured soil, and become dangerous in deep wounds which demand early treatment. Vaccination against tetanus would be wise for farm workers.

Food-poisoning Bacteria—Various types which affect animals include some Salmonella bacteria, also dangerous to humans. All farm animals and birds are susceptible to different types, and usually suffer from fever and dysentery, and often die: their dung may remain infective for some months. Rats and mice may spread infection by soiling food, water or litter (e.g., rats infesting straw sttacks or food stores).

Infectious Jaundice—Organisms are excreted in urine or other discharges and can penetrate unbroken skin. This demands even more careful personal hygiene.

Human diseases are also spread from humans to milk thence to milk consumers, e.g., Streptococcal sore-throats. Sick dairy workers should stay away or be transferred to other work.

COMMON DISEASES OF THE COW

Tuberculosis, Anthrax, Foot and Mouth Disease. (See *Notifiable Diseases.*)

ABORTION AND STILLBIRTHS

Abortion is the premature birth of a dead calf at any stage of pregnancy. Stillborn calves are delivered dead at full-term. Some calves which are born prematurely by only a week or so may live, yet carry certain infections. Veterinary advice should be sought whenever abnormal births occur, in order to distinguish the several different causes.

Brucellosis (contagious abortion)—*Brucella abortus* bacteria infect the womb and placenta (" afterbirth "). The calf may be aborted (" slipped "), often at fifth to seventh month of pregnancy, or may be born weakly after the eighth month, and often dies. Some are born dead at full term, others appear normal, healthy calves. Any calves which

survive may spread infection in dung for several months. The afterbirth frequently requires manual removal; this and any discharges are highly infective. Milk is also infected for a variable period (perhaps a few months).

Spread of Infection—By aborted calf, afterbirth, discharges and milk. These contaminate pasture, food and water. Also by dirty hands and unsterilised calving ropes. Bulls sometimes become permanently infected but also might carry disease after mating infected cows.

Diagnosis—Aborted calves with afterbirths can be examined in a laboratory. Blood tests will reveal infected cows.

Treatment—None fully reliable.

Prevention—Burn or bury aborted calf and afterbirth. Isolate cow until discharges cease, preferably in an easily disinfected loose-box. Heifer calves should be regularly vaccinated, when four to eight months old, with S.19 Vaccine. There is a Government subsidised scheme, arranged through veterinary surgeons. Resulting immunity persists for five or six pregnancies. Adult cows should be vaccinated if not done previously, when epidemic threatens. Purchase cows certified free from infection, or certified vaccinated as calves.

Genital Vibriosis—*Vibrio foetus* bacteria differ from *Brucella abortus* in soon dying when outside the animal body. Infection similarly occurs in womb and placenta. Some abortions occur, but earlier, at fourth to fifth months of pregnancy.

Widespread herd infertility is the major symptom, with cows returning to service at irregular periods.

Infection is spread by service by an infected bull.

Diagnosis—Requires a veterinary surgeon, since other causes of infertility exist. Full records of matings, and purchases of cattle, greatly assist diagnosis.

Treatment—Antibiotic treatment is 90–95 per cent. effective; or at least six months rest of cows from service. Best control is by artificial insemination which prevents further spread of infection. The infected bull may have to be slaughtered, but treatment may be tried, then "test-mating" to a group of heifers, before returning him for use on known healthy animals only.

Trichomoniasis—*Trichomonas foetus* is a larger organism (Protozoon) which causes infertility similar to Vibriosis, also early abortions, e.g., nine to twelve weeks, and is also spread by infected bulls. It is now rare in Great Britain, due to control by widespread use of artificial insemination.

Mastitis (Garget)—This is any inflammation of the udder, but usually refers to bacterial infection. *The acute type* causes swelling and pain in the affected quarter, with clots in the milk, and constitutional disturbance (fever, inappetence). Less severe general symptoms are seen in the *sub-acute type*, but udder and milk changes may still be considerable. The *chronic type* may follow either of the above forms, or may occur primarily. The affected quarters slowly become enlarged and firm (indurated), or may shrink. Milk yield gradually becomes less, with or without presence of many clots.

Changes in the milk vary with different bacterial infections. Milk may be blood-tinged and contain large fibrinous shreds. It may resemble whey, with caseous clots. Secretion may resemble pus. Chronic mastitis may cause so slight a change that small, pin-head sized clots are only seen when using a strip cup for fore-milk.

Diagnosis—Identification of bacteria is a laboratory procedure. Milk samples must be taken from untreated animals into sterile sampling bottles, with precautions to avoid contamination by dirt or scurf from the udder.

Contagious types of mastitis depend on spread of causal bacteria from cow to cow, e.g., *Streptococcus agalactiae*, which is readily carried by infected milk, and by contaminated hands, udder cloths and milking equipment.

Non-contagious mastitis is initiated by even slight damage to udders or teats; this assists entry of bacteria which are normally present on or inside the udders of most cows. These predisposing causes include teat sores, prolonged milking times, badly fitting or perished rubber liners, etc., and are not always readily apparent.

Bacteria involved in the above types of mastitis include *Staphylococcus pyogenes* (*Staph. aureus*), *Streptococcus dysgalactiae* and *Strep. uberis*.

Summer Mastitis is caused by *Corynebacterium pyogenes* with Streptococci. Onset of inflammation is sudden and considerable amounts of foul-smelling pus are secreted. The

affected quarter seldom revives, except with very early treatment, and severely affected animals may die.

Other types of Mastitis are caused by *tuberculosis* (which produces chronic induration of the affected quarter), *Bacterium coli* (acute onset, with constitutional upset, e.g., fever and inappetence), and various types of moulds.

Treatment—Streptococcus agalactiae responds well to penicillin and can be eradicated from a herd by repeated treatment of carrier cows identified by milk tests. Good milking hygiene reduces risk of re-infection.

Non-contagious Mastitis—There is variable response to modern treatments by these different bacteria: *Staphylococcus pyogenes* may be cured by penicillin, but 25 per cent. of strains isolated may prove resistant, when different treatments will be necessary. The other *Streptococci* can be cured by antibiotics. This type of mastitis will recur unless teat sores and injuries are overcome and milking machine technique is corrected.

Summer Mastitis which affects mainly dry cows and heifers is only cured by prompt treatment with antibiotics. Dry cows and heifers should receive preventive injections of penicillin into each teat before turning out to grass just before the seasonal occurrence of this disease in the summer. Teats may also be sealed by collodion. Dry cows should be inspected twice daily at this time. Occasional cases also recur throughout the year. Infection may be spread by flies attracted to drops of pus on the ends of teats, which should be kept clean. Fly-deterrent sprays can be used on animals and in byres, whilst manure should be heaped carefully to limit fly-breeding.

Vaccination against mastitis has not yet been proved to produce adequate immunity, but research into this is being continued.

Johnes Disease—*Mycobacterium johnei* organisms are related to Tuberculosis. They infect the bowel wall, causing profuse diarrhoea and rapid loss of flesh, ultimately death, especially after calving or other general strain has weakened animals' resistance. Dung is often bubbly and foul-smelling. Calves are most susceptible to infection, which then remains dormant for one to two years before causing symptoms in adult animals. Severely affected cows may infect their embryo calves before birth.

Infection is spread by infected dung. Affected animals may intermittently shed bacteria in dung before definite disease symptoms are seen. The bacteria can survive for a year on moist, shaded pasture, notably orchards, stream and pond margins, surrounds of water troughs and muddy gateways.

Diagnosis is suggested by typical symptoms but should be confirmed by laboratory tests of blood and dung.

Treatment by intestinal astringent mixtures and dry feeding may relieve the diarrhoea but permanent cure is unlikely. Apparently recovered cows may continue to spread infection. Suspected cases should be isolated until slaughter is practicable.

Control Measures include slaughter of infected animals, bucket-feeding of calves (to avoid infection through dung contaminating the udder), and avoidance of communal use of yards or paddocks by calves and adult cattle. Manure should be used on arable land, not grazing pastures. Watering facilities should be improved, also drainage of wet fields.

Control by slaughter of reactors revealed by regular herd blood tests has proved satisfactory *when the above improvements are also carried out.*

Vaccination—Experimental trials are encouraging but not yet available for general use.

Infertility—Failure of female animals to conceive, or male animals to promote conception. It can be either temporary or permanent, curable or incurable. Single animals may be affected, or the majority of a herd. There are various causes which can only be differentiated by expert veterinary examination; some require laboratory tests. Diagnosis is greatly aided by careful records of service dates, bulls used, names and dates of purchase of new animals.

Infections—Infertility can result from *Brucellosis, genital vibriosis, trichomoniasis* (see these diseases).

Causes—Functional disorders of the reproductive system can be associated with unbalanced diets; they include lack or excess of major food constituents such as protein; deficiencies, or imbalances of minerals and vitamins; actual starvation (perhaps of a low level only). Examples of such disorders are so-called silent heat (in heifers on poor winter feeding),

" whites " (abnormal and excess vaginal discharges), and repeated returns to service.

Bulls' fertility is also affected by diet. Strain, e.g., excess use of a bull, high milk yields with inadequate rest between lactations, and ill-health from debilitating diseases, also cause disturbed reproductive function.

Inherited faults include white-heifer disease and other disorders of the structure or function of the reproductive system of either male or female animals.

Treatment should not be attempted without seeking veterinary advice early, to prevent interference with the breeding programme in your own herd and to avoid introduction of disease into other herds by sale of infected stock.

CONSTITUTIONAL DISORDERS

These include conditions such as Milk Fever, Acetonaemia, Grass Staggers (Hereford Disease) and Bloat (Hoven).

Causes are not always exactly known but normal body functions can be upset by undue strain of production demands, e.g., high and prolonged milk yields, also by sudden changes of diet.

Treatment aims to alleviate the symptoms, correct possible predisposing causes, until the animal's body becomes re-adjusted to normal.

Milk Fever—Not a feverish condition, ears and horns feel cold. Recently-calved cows are affected, usually within 24–48 hours after calving. It rarely occurs before calving, or is delayed long afterwards in cows (in sheep and pigs it occurs at different times).

The level of calcium in the blood falls below normal due to lack of normal control by hormones. Nervous symptoms include general uneasiness, " paddling " of the hind legs, progressing to excitement and violence. Later, the animal lies down, either stretched out on its side, or characteristically with its head turned round into the flank. If untreated, coma occurs and is followed by death. Complications are cessation of rumination, defaecation and urination.

Treatment—Injections of soluble salts of calcium; other mineral salts may also be given to compensate for imbalance of magnesium and phosphorus which may accompany milk fever. The udder should only be relieved, never milked out,

for 4–7 days afterwards. Diet must be laxative, not rich or forcing.

Prevention—Milk fever is not due to low calcium in the diet. Excess calcium can be harmful, by interfering with hormone control by the parathyroid endocrine glands. The diet should be well balanced and include essential minerals. Steaming-up should be light, for cows known to be susceptible, and they should be milked lightly for the first week.

Grass Tetany (Hereford disease, grass staggers)—Blood level of magnesium falls, again probably due to breakdown of hormone control. Low levels of herbage magnesium may predispose to grass tetany, as also grass flushes in spring or autumn, stimulated by large dressings of nitrogenous fertilisers. Cold, wet weather at such times often brings on attacks.

Symptoms—In cows, 2–3 weeks after calving, symptoms resemble milk fever but with nervous excitability, violent fits, coma and rapid death (which may take place with few preceding signs, and must be differentiated from Anthrax before the carcase is cut). Young stock react similarly.

Treatment—Injection of soluble salts of magnesium (perhaps with other minerals). Keep affected animal quiet and warm and remove other stock to rougher pasturage. Feed hay and magnesium salts.

Prevention—Feed magnesium-rich mineral mixtures before and over the initial season. Dolomite limestone can replace ordinary liming of pastures and provides extra magnesium. Avoid sudden change to flush grass, and provide shelter from inclement weather.

Acetonaemia—A world-wide condition which affects high-yielding dairy cows, usually within three weeks after calving, seldom later. It is more prevalent during the winter or stall-feeding periods in Great Britain. Acetonaemia is an upset in liver function resulting in circulation in the blood of ketones, which are intermediate products in the digestive processes. Ketones also appear in milk and urine. The exact causes are not known, but disturbance of hormone balance and strain of high production are probably involved, and nutritional factors cannot be ruled out.

Symptoms—Appetite is lost, milk production falls and constipation occurs. Loss of body weight may ensue, and

some cases become highly excitable. There is a characteristic sickly-sweet odour of the breath, and cows frequently grind their teeth.

Diagnosis is based on symptoms, aided by tests of milk or urine, but sometimes it is difficult to rule out other conditions causing similar symptoms.

Treatment includes injections of glucose solutions, administration of sodium propionate, glycerine, and other drugs of variable effectiveness. Hormone-like injections are helpful in some cases. Changes in the diet, e.g., increasing the carbohydrates, may be tried but experimentally do not seem to influence prevention or recovery.

Bloat (Hoven, rumen tympany) is distention of the rumen (bulging the left flank region) by gas or frothy fermenting green food. Respiratory distress results from pressure on the chest. In *acute* cases death may occur within one to two hours of access to lush grass, clover, or frosted foods. Spoiled food (mouldy, etc.) is similarly harmful. *Chronic*, less severe cases, may be caused by indigestion, foreign bodies in the second stomach, tumours and infections of the stomach linings.

Treatment—Acute cases of great distention require urgent attention by releasing gas by puncture of the highest part; a trochar and cannula is preferably used, or a knife in emergencies. Frothy bloat is not relieved by this operation, as gas is trapped in the fermenting food. Silicones and other surface-tension reducing agents are given, by mouth or via the cannula. Less urgent cases respond to doses of 2 ounces of turpentine in 1½ pints of raw linseed oil. Persistent cases require veterinary advice, e.g., to remove foreign bodies in gullet or rumen.

Prevention—Feed hay or straw before grazing lush pastures, and strictly limit first feeds on these (e.g., strip graze). Avoid frosted or other spoiled foods, or immature roots.

Foul in the Foot (Foot rot) is inflammation between the claws caused by infection of abrasions by bacteria present in soil or dirt. Frequently seen in hind feet after injury by stones (e.g., rough tracks) and further aggravated by stubble or other rough-stemmed herbage. Constantly muddy fields assist by softening the skin. Foot rot may commonly occur on some farms, seldom on others.

Symptoms—First seen is lameness, accompanied by heat and swelling between the claws and above the hoof. Abscesses may develop and involve tendons or bones of the foot. N.B.—Foot and Mouth disease must always be considered when lameness occurs.

Treatment—Early injection of one of the sulphonamide drugs is usually a specific cure. Removal of "proud flesh" may be necessary, or, in advanced cases, amputation of a claw; both by a veterinary surgeon. Protection by bandages is essential during the healing stages.

SKIN DISEASES

Several kinds may occur together, necessitating diagnosis by laboratory tests of skin scrapings. Most cause, or result from, unthriftiness, rapidly spread, and may affect humans.

Lice—Both blood-sucking and biting lice cause skin irritation, scurfiness and unthriftiness, more commonly in calves.

Treatment—(See Mange.)

Mange (Itch)—It is uncommon in Great Britain. Cuased by microscopic skin mites; some prefer the tail base or neck region, others less hairy parts of the body; producing pimples, general irritation and scratching, with loss of hair and scurfiness.

Treatment is best by application of gammexane preparations (more persistent effectiveness than lime and sulphur type dips).

Warbles—These are swellings under the skin on the back containing the maggots of the Warble Fly. These hatch from eggs laid on hairs on legs and lower flank during the summer, migrate through the body and reach the backs in late winter or early spring (November–March). After breaking out through their breathing holes, the maggots fall to the ground and pupate and hatch later in the summer into Warble Flies.

Treatment—A Government Order requires cattle to be treated every 10–15 days from March until June, but in southern England Warbles appear earlier in the year and treatment should be applied *as soon as they can be detected.* The individual maggots can be squeezed out or, preferably,

derris preparations should be *scrubbed* into the breathing holes.

Prevention—Fly-repellent sprays applied to the legs and flank help to deter egg-laying. Careful, regular and thorough derris application, over a period of years, is the best control measure. Concerted action by all farmers can greatly reduce Warble Fly damage to hides, and loss of milk by cattle "gadding." This has been demonstrated in the Isle of Wight campaign. Dosage of cattle with larvicidal drugs has been tried experimentally, with some success.

Ringworm—A highly contagious fungus infection of the hairs, resulting in loss of hair in more or less circular patches, mainly on face and neck but also on other parts of body. Eventually, areas become scabby. Humans are also readily infected ("Dairyman's itch"). More common during winter months on yarded cattle, but may occur throughout the year.

Treatment—Scrub off scabs using a piece of rough sacking (burn this afterwards) and hot water and soda. When dry, affected areas and a wide margin around should be painted with one of the proprietory fungicidal preparations. Iodine preparations, creosote and linseed oil, etc., are also curative, but sump and other oils can be harmful.

Prevention—Ringworm spores live for many years in old woodwork. If possible this should be scorched carefully by blowlamp, then creosoted.

Cow Pox—This virus infection can cause rapid spread through a collection of small skin blisters, which burst to become sores, affecting teats and udders. The disease runs its course in 4–6 weeks, and results in increased resistance to further infection for a year or so. No permanent damage remains, but the ulcers interfere with milking, and may induce mastitis.

Treatment—Antiseptic or antibiotic ointments prevent bacterial infection. Milkers must avoid undue friction whilst stripping.

Warts ("Angleberries")—These are troublesome on teats. Some are infectious (virus). Ligatures of silk or

thread readily remove those with distinct necks. Some "Wart ointments" and injections may be effective.

Actinomycosis and Actinobacillosis ("Lumpy jaw" and "wooden tongue")—The first condition is caused by microscopic fungus-like bacteria which penetrate through small wounds in the mouth, e.g., caused by barley awns, foreign bodies, or during change of teeth, and cause swelling of the jaw-bone with ultimate suppuration.

In *actinobacillosis*, different bacteria cause similar changes in the tongue and neighbouring soft tissues, and often involve glands in the neck or other regions, also affect the stomach, sometimes the udder.

Symptoms—First seen are salivation and difficulty in masticating food. Glands in the throat become abscessed and burst. Infection in the stomach causes indefinite symptoms, but interference with digestion can result in progressive wasting.

Treatment—Iodine drugs given by injection and by mouth, also certain antibiotics, will control actinobacillosis if given early, but actinomycosis (lumpy jaw) is less responsive to any treatment. Abscesses are poulticed, drained and treated carefully to avoid spreading infection.

Prevention—When cases occur frequently, infection is probably being spread by communal water or food troughs, ponds, or scratching posts.

Redwater (piroplasmosis)—Caused by microscopic parasites entering and destroying blood cells. The haemoglobin released is further changed, and is passed out to give urine the characteristic reddish-brown or coffee colour. There is no whole blood excreted (as occurs in other conditions).

Ticks (*Ixodes ricinus*) carry the parasites to healthy cattle and inoculate the disease by their bites.

Symptoms—Include urine discoloration, which may only be transient, high fever (106–107° F.), anaemia, listlessness, constipation, and death. Calves show no symptoms, and derive immunity early in life if infected. Adult stock brought in from redwater-free districts are highly susceptible.

Treatment—Early injections of specific remedies rapidly cure unless delayed until constipation has set in, when

death is probable. Purgatives, light laxative diet, and ample water are essential.

Prevention—Eliminate ticks by destroying their shelter, i.e., scrub, rough pasture. Gammexane type sprays of cattle, and sheep dipping, kills ticks and parasites effectively on the skin for several weeks. Sheep can be run over infested pastures to collect ticks, then be dipped.

Susceptible adult cattle should not be introduced on to infected farms.

Tick-borne Fever—A disease of the blood affecting the white blood cells; also carried by ticks. Adult cattle are again affected.

Symptoms include fever (105–107° F.), sudden fall in milk yield, but no discoloration of urine. Seldom fatal, animals recover in 4–7 days, aided by veterinary treatment.

Control Measures—(See tick control, Redwater.)

Black Quarter (felon)—Spores of *Clostridium* bacteria are long-lived in soil and infect minute wounds. Young stock (aged 6–30 months) are chiefly affected.

Symptoms—Sudden deaths are common in young stock, without previous symptoms. Others are feverish, lame, with limbs swollen, hot and painful. The swellings are doughy at first, later ballooned by gas which crackles when the skin is pressed. If burst open, these emit a rancid odour.

Treatment—Temperatures should be taken of all in-contact animals, and those showing fever should be given anti-serum and penicillin injections.

Prevention—Vaccinate young stock every six months until 2–2½ years old. Burn affected carcases. N.B.—Sheep of all ages suffer from a similar disease, especially after difficult lambing (often assisted), or when shearing or dipping causes injuries.

DISEASES OF CALVES

Calf ailments are most commonly the result of incorrect methods of feeding and cold, draughty pens.

White Scours—*Bacterium coli* normally inhabit the intestines, but certain types are more harmful and can be introduced to home-bred calves by purchased animals. Indigestion, e.g., from faulty bucket-feeding, encourages rapid growth of the harmful bacteria.

Symptoms—Whitish-yellow diarrhoea in young calves a few days old up to 3–4 weeks. Often fatal.

Treatment—Starve the calf for 24–36 hours, dose with 2 oz. castor oil, and re-introduce food as half milk, half warm water, gradually returning to whole milk over 4–5 days. Medicines include various intestinal astringent mixtures, sulphonamide drugs, and antibiotics. Antiserum inoculations may assist.

Prevention—Careful feeding. Good hygiene of buckets and pens. Warmth. *Bact. coli* antiserum inoculations at birth offer extra protection which may be lacking in colostrum. Repeated buying-in of calves should be avoided.

N.B.—Other forms of diarrhoea in older calves (up to 6 months) can be caused by *coccidiosis*, also by *Salmonella* bacteria (food-poisoning organisms) some of which affect humans, and by *Clostridium* bacteria (see "pulpy kidney" disease, Sheep).

Pneumonia—Various bacteria and viruses may infect the lungs, usually after the animal's resistance has been reduced by cold, draughty or damp housing.

Symptoms—These include fever, rapid breathing, nasal and eye discharges, often diarrhoea. Certain infections can spread rapidly and may be carried on contaminated clothing.

Treatment—Isolate affected animals in warm but airy pens. Attend to them *after* healthy stock, preferably by a separate worker. Veterinary advice is essential for correct diagnosis and treatment of the specific cause; antiserum and vaccines are available for some. Others require antibiotic injections or sulphonamide drugs.

Navel or Joint Ill—Unhygienic conditions at birth allow infection (often *Bact. coli*) to enter the navel-cord before this properly heals. Rapid septicaemia may cause death within 2–3 days of birth, or chronic abscesses may form in swollen limb joints or in any organ in the body, causing either lameness or unexpected death with few prior symptoms.

Lambs and other new-born animals can be similarly affected. Lambs are more prone when the same fields or yards are used for lambing ewes over several years.

Treatment—Antiserum, antibiotics and other drugs may be successful if given early.

Prevention—Calve down cows in clean, disinfected loose-

boxes. Tie-off the navel-cord with clean tape soaked in tincture of iodine, or dip it into a small jar of iodine without handling the cord. Inoculate *Bact. coli* antiserum immediately after birth.

PARASITIC DISEASES

Young animals of all species are more liable to suffer from internal or external parasites than are adult stock, which usually have acquired some immunity, although possibly still carrying sufficient parasites to infest pastures and thence their young.

By the time characteristic symptoms of diarrhoea and loss of flesh are noticed, treatment may be ineffective or recovery slow. Good management, frequent rotation of grazing, and regular treatments for parasites are the best precautions for all types of animals.

Coccidiosis—Protozoan parasites invade the bowel wall, causing ulceration and diarrhoea, often blood-stained. Each species of animal has its own species of coccidial parasites. Infection is spread by dung contaminating food or litter.

Treatment—Sulphonamide type drugs, or the more recently introduced nitrofurans, are given by mouth for 3–5 days. Floor litter should be removed and destroyed every second day, and food and water troughs thoroughly scrubbed, disinfected and so placed to avoid soiling by dung.

Worms—These are taken to mean the internal parasitic worms which inhabit the stomach or intestines (different parts by different worms), where they cause indigestion and more serious digestive disturbances.

Symptoms—Diarrhoea, innappetence and loss of flesh commonly occur. Some worms ulcerate the stomach wall and cause anaemia by sucking blood. All parasitic worms lay eggs which are passed in the dung and require a period of development on pasture before becoming infective to another animal. A high proportion of these infective larval stages die out over a period of six months, especially if desiccated by exposure to sunlight. It should be noted that very heavy infestations of immature worms can cause fairly quick deaths before they mature and lay eggs.

Stomach and Intestinal Round Worms (Cattle, sheep and goats)—The condition they produce is called

parasitic gastro-enteritis. Symptoms are as quoted above. These worms are thread-like and pass out in the dung unnoticed.

Cattle—They suffer most during their first six months at grass; " nursery " paddocks are often hot-beds of infection (sheltered orchards are especially dangerous).

Treatment—Phenothiazine, with careful dosage, may be given from three weeks after first turning out, repeated monthly if necessary. Sometimes calves are hypersensitive to phenothiazine, usually when exposed to strong sunlight afterwards, and a few should be dosed first as a precaution, then kept indoors for 24–48 hours.

Sheep—Symptoms are seen a few weeks after lambs begin to eat grass. Ewes may also suffer if overstocked on poor pasture. When folded, sheep should not be allowed more than two days' run-back, as this area can be heavily infested with worm larvae.

Treatment—Phenothiazine is most commonly used but a few types of worm are not destroyed by it. Dosage may begin at $2\frac{1}{2}$–3 months of age, and be repeated at monthly intervals if necessary. Usually, two doses in the spring and another one or two in the early autumn suffice.

Copper sulphate and nicotine sulphate solution, although sometimes harmful, is also effective, but less so than phenothiazine.

Nematodirus species of intestinal worms are very harmful to lambs, which become affected through grazing fields used by similarly affected lambs during the previous year. Ewes are not carriers of heavy infestations, unlike the case of other types of worm. No satisfactory treatment is yet known, but affected lambs must have access to ample fresh water to counteract the profuse diarrhoea which is characteristic of this disease. Weak salt solutions may also be given. This disease is controlled during the following year by the new lambs grazing only fresh pastures, e.g., leys, or fields which have not been contaminated by nematodirus larvæ, or at least by avoiding such fields during the critical months from late April and in May, June and July.

Tapeworms—These are only harmful to lambs when numerous, and require special treatment with lead arsenate preparations, under veterinary advice. Phenothiazine is ineffective.

Gid or Sturdy—Tapeworm cysts pressing on the brain cause symptoms in older sheep of "circling" to right or left, or other abnormal carriage of the head. The actual tapeworms live in the intestines of dogs, which should be treated to eliminate these, thus reducing contamination of fields used by dogs.

Pigs — Large roundworms are common causes of unthriftiness. They are easily visible, being 6–10 in. long, creamy-white in colour. Piglets swallow eggs when suckling udders soiled by dung, or by grazing contaminated fields.

Symptoms—These include unthriftiness, diarrhoea or constipation, poor or even voracious appetite, perhaps death in convulsions.

Treatment—Remedies include *oil of chenopodium* (5 per cent. in castor oil) dosed to individual animals after starvation (½–3 tablespoonsful according to age); *sodium fluoride* is easier to administer, being given in *dry food* at the *recommended dose for the weight of pig* (according to manufacturer's instructions). *Piperazine* drugs are similarly given and less likely to be harmful if accidentally overdosed.

Sows, being the common source of infestation for younger pigs, should be treated as late in pregnancy as possible (preferably with piperazine drugs) then transferred to clean farrowing pens. They may be washed with soap and water before farrowing to remove infective dung from their udders.

Liver Fluke Disease (liver rot, bane, or cord)—Flukes (*Fasciola hepatica*) can affect livers of cattle as well as sheep, and rabbits may carry infestations. *Acute disease* is due to very heavy infestations of the liver by immature flukes, causing fairly sudden deaths of even fat sheep without the usual symptoms seen in less severe disease. *Chronic disease* results from mature flukes producing irritation and thickening of the bile ducts in the liver. Affected sheep lose condition, weaken, and may show swelling under the jaw. This form commonly occurs late in autumn, whereas the acute disease is seen in late July or August. *Cattle* suffer less severely but damage to their livers results in condemnation of up to 70 per cent. of abattoir livers. Milk yield can be lowered and indigestion, diarrhoea, and "bottle jaw" are other symptoms. Diagnosis can be confirmed by laboratory examination of dung samples.

Treatment—Sheep; carbon tetrachloride capsules, usually 1 c.c. doses, are given monthly from September to October; two doses may suffice on lightly affected farms, but it can be repeated every month or two months. Extracts of *male fern* are also used. Sheep on rich pasture or concentrate food should be given poorer diet for a week before and a few days after treatment to avoid risk of poisoning, and trial dosage of two or three sheep is advisable.

Cattle—These should *not* be given carbon tetrachloride; *hexachlorethane* is used in the dosage recommended by the manufacturers. Lactating cows should be dosed in small groups to avoid possible lowering of the bulk milk yield which might follow herd treatment.

Prevention—Young stages of the liver fluke require to develop in a mud-snail. Eggs from adult flukes pass out in cattle or sheep dung, hatch within 2–20 weeks under suitable conditions of warmth and moisture, and the larvae invade the bodies of these snails. There they multiply and after 6–7 weeks leave the snails, swim up grass blades and form cysts; many of these die within two months. Control, therefore, is by preventing damp, muddy conditions to discourage snails. Stream margins, surround of water troughs and green " flushes " around springs should either be fenced off or drained. Copper sulphate (one part to four parts of sand) can be scattered over such areas during the summer; three applications should suffice but it must be remembered that a few snails can multiply very rapidly again.

Lungworms, Husk or Hoose—Different types affect cattle, sheep and pigs, usually young stock, but adult animals may be equally susceptible if never previously exposed to infestation. The fine, threadlike worms live in the air passages in the lungs, and cause bronchitis, husky cough and sometimes nasal discharges. Animals lose weight, may die from bacterial infections. *Diagnosis* can sometimes be confirmed by laboratory examination of dung samples, but acute husk may develop before egg-laying commences.

Treatment—Injections into the windpipe are used but are of doubtful value. Certain proprietary drugs offer more promise and are given either by mouth or injection. Affected animals should be removed from pastures and given supplementary concentrate foods and mineral mixtures.

Intestinal worms usually occur at the same time and appropriate treatments for these hasten recovery.

Prevention—Mixed grazing of stock permits destruction of larvae by non-susceptible animals. Similarly, heavy grazing by adult and young stock together also reduces the burden of pasture infestation. Young stock should not *follow* adults as the latter may carry a few worms and thus re-infest the ground. Harrowing of dung pats favours development of larvae and should be avoided where possible.

Sheep also suffer from husk, usually lambs during their first winter. The species of lungworms are different from those affecting cattle. Husky coughing is noted in a number of the flock and parasitic gastro-enteritis and malnutrition frequently aggravate debility. Treatment and control measures resemble those for cattle.

DISEASES OF SHEEP

Foot and Mouth Disease, Sheep Scab and Anthrax are described under Notifiable Diseases.

Parasitic Gastro-enteritis (Worms)—This is one of the major causes of economic loss in sheep (see Parasitic Diseases of Animals).

ENTEROTOXAEMIC DISEASES

Under certain conditions, *Clostridium* type bacteria, normally present in the intestines in small numbers, multiply rapidly, produce toxins which are absorbed and cause the various symptoms. Sudden changes from poor to good feeding are commonly responsible. Different toxins cause different diseases, viz.:—

Lamb Dysentery—Common in North England, North Wales and South Scotland. Lambs 7–10 days old either are found dead or suffer diarrhoea (often blood-stained); up to 50 per cent. soon die.

Pulpy Kidney—Widespread over Great Britain. Older lambs are usually affected (at 6–16 weeks), sometimes also older sheep. Calves may also be affected. The best thriving animals are found dead, rarely seen ailing. Lambs suckling full-milking ewes, or grazing lush grass, most commonly suffer. Folded sheep are susceptible when moved to fresh fold crops.

Prevention—Similar measures are used for both diseases. Specific antiserum is available against each; that for lamb dysentery also affords fairly good protection against pulpy kidney disease, but in each case the immunity only lasts for 3–6 weeks. *Lamb dysentery* antiserum should be injected into lambs immediately after birth, or *ewes* may be *vaccinated* before tupping and again 1–2 weeks before lambing; their milk then supplies protective antibodies to the suckling lambs.

Pulpy kidney antiserum is injected just before the first losses are usually expected. *Vaccine* is often used simultaneously, and repeated in a few weeks' time to confer more lasting immunity.

Struck—This is not to be confused with "fly-strike." Sheep over one year old are found dead, rarely showing prior symptoms, e.g., dullness. The condition occurs in late winter and spring, mainly on Romney Marsh, Kent, sometimes North Wales and elsewhere; losses are often confined to certain fields.

Prevention—Two injections of vaccine are given, 14 days apart.

Diagnosis of the different types of *Clostridium* infection is guided by post-mortem examinations but should be confirmed by laboratory tests on *fresh* carcase material.

Braxy—Also caused by *Clostridium* bacteria, *Clost. septique*. This kills yearling and older sheep on hill grazings in North England and Ireland, during autumn and winter months. Frosted herbage causing indigestion induces it.

Diagnosis—This is only possible within one hour of death; the typical change seen is severe inflammation of the fourth stomach.

Prevention—Vaccination in early September.

Blackleg (gas gangrene)—*Clostridium chauvoei* invade the body of ewes through injuries, often at lambing, shearing or dipping; lambs are infected at castration or docking.

Symptoms—These show within 2–4 days, mainly stiffness of the legs, swelling of the hind quarters, pain and distress. Death follows in a few hours. *Diagnosis* is based on symptoms and changes seen in the muscles, which are dark in colour, possibly gassy, and emit a characteristic odour.

Prevention—Vaccinate ewes 3–4 weeks before lambing. Antiserum can be given at the time of lambing or dipping, shearing, or tailing and castration. Cleanly operations greatly reduce risk. *Combined vaccination* is available against braxy and blackleg.

Tetanus (lockjaw)—*Clostridium tetani* infect principally deep wounds. The bacterial spores commonly exist in soil, especially in the presence of organic matter such as manure. Lambs are infected at castration or tailing, more rarely via the navel at birth.

Symptoms—These may be delayed for 1–3 weeks after infection, and include limb stiffness, head thrown back, sometimes muscular spasms. Mildly affected cases may recover.

Prevention—Antiserum may be injected at the time of operations but it may be ineffective when symptoms have developed. Risk is reduced by hygienic operations in clean pens.

N.B.—*Horses* are affected more severely, usually following deep pricked wounds in the feet or stake injuries while jumping. *Cattle* are less prone to infection, less severely affected. *Pigs* suffer similarly to lambs. *Humans* are also susceptible, mainly through deep or pricked, dirty wounds. Vaccination of farm workers would be a wise precaution.

Mastitis (garget)—Caused by a variety of bacteria, including staphylococci. More common in folded flocks on arable land and during wet, cold weather. Disease occurs from a few days to a few weeks after lambing.

Symptoms—Inflammation rapidly develops, followed by blackening and gangrene of the affected half of the udder. Death may take place early, or recovery follow sloughing of the affected tissue. This may be helped by amputation of the teat or udder.

Treatment—Antibiotics must be injected promptly. Injections of toxoid in late pregnancy may increase resistance to infection.

Infectious Abortion—Two main bacterial causes are *Vibrio foetus* (different strain from that affecting cattle), and *Salmonella abortus ovis*. The former is widespread in England and Wales; the latter is more localised, principally in

south-west England. Both types are introduced by carrier animals, themselves immune, which contaminate pasture and water supplies. Mating may further spread infection.

Symptoms—*V. foetus* causes abortions from the second month of pregnancy. Abortions due to *Salm. abortus ovis* begin about 6 weeks before lambing is due; 10–40 per cent. ewes may abort, even 60–70 per cent. at times. A proportion of ewes die.

Diagnosis—Only confirmed by laboratory tests on several aborted lambs, the afterbirths, and by blood tests.

Prevention—No treatment is known. Once affected, ewes remain immune, but some will spread infection to susceptible animals which may be bought-in, or start infection in a new flock if sold. After abortion, a flock should be kept "closed," and only a few further abortions are likely in subsequent years.

Enzootic Abortion (Kebbing)—Virus infection of the placenta causes abortion about 10–14 days before lambing is due, or dead or weakly lambs may be born at full term. The virus survives only a few days outside the animal. Prevalent in lowland flocks in south-east Scotland and north-east England, rare in hill sheep or elsewhere in Great Britain; 10–15 per cent. ewes may die.

Diagnosis—This is based on symptoms and laboratory tests of afterbirth and blood samples; aborted lambs are not helpful.

Prevention—*Vaccines* are available, but must be used over several seasons before benefit is apparent. Since infection is spread during lambing or abortion, crowding of ewes should be avoided; newly infected sheep will abort during the next lambing season. Aborted lambs and all (even healthy) afterbirths should be destroyed (by burning, burying, after temporary collection in tanks of disinfectant). Affected ewes should be isolated, especially from ewe hoggs, for 4–6 weeks after abortion; they should only foster male lambs.

Foot Rot—A contagious disease causing evil-smelling discharges to under-run the wall and sole of the feet, with severe lameness, loss of body condition and even death from septic infections. The causal bacteria live in the soil but die out if pasture is rested from sheep for 2–3 weeks.

Treatment—Several types of foot dressing may be used but none are likely to be effective unless the affected feet are properly pared absolutely clear of the diseased horn. After paring, foot-baths of 5 per cent. formalin or 8 per cent. *copper sulphate* solutions can be used, or these well brushed-in by hand dressing. Various antibiotics are also available, but require the same thorough preliminary paring of the feet. Affected sheep should be grazed separately from healthy, inspected every 2–4 days, and diseased feet again pared and re-treated. Healthy sheep should graze pastures rested from sheep for at least 14 days. Foot and Mouth disease can also cause widespread lameness.

Louping Ill (Trembles)—Virus infection is carried to susceptible animals by ticks. The disease is so far mainly confined to northern England and Scotland but is sporadic elsewhere. Disease occurs more severely during April–June and again in September–October. Cattle, horses, pigs and humans may also contract louping ill.

Symptoms—Acute fever develops 6–18 days after infection, with dullness and lack of appetite. Five to ten days later nervous symptoms develop, viz., excitability, tremors of head and neck muscles, unsteadiness (if made to move a sheep may fall), eventually paralysis. When driven by a dog, some sheep jump jerkily or show high-stepping walk with head held high. Deaths are more common in younger sheep (perhaps 4 per cent. in yearlings). Sheep introduced from tick-free areas may suffer 60 per cent. mortality.

Symptoms may seem to resemble lambing sickness, but this is only seen in ewes in late pregnancy or lactation, and responds readily to treatment, whereas there is no specific treatment for louping ill. Shelter, quiet, and good nursing enable some to recover.

Prevention—A vaccine may be used on all but very young lambs. Tick control is essential.

Tick-borne Fever—This infection of the blood cells is also carried to sheep by ticks. It is seldom fatal, except when other disease supervenes in a weakened animal. Recovered sheep are immune but may carry infection for up to 2 years. Lambs infected soon after birth are rarely ill and their immunity is reinforced every subsequent year they remain on tick-infested land.

Symptoms—Fever for only 2–3 days, or falling slowly to normal over a period of 2–3 weeks. Pregnant ewes often abort; this is most severe on their first encounter with infected ticks during pregnancy. Home-bred flocks suffer less.

Treatment—Sulphonamide drugs and antibiotics are useful, but may interfere with immunity. As yet, vaccines are of limited value.

Scrapie—The infective agent is probably a virus but method of spread of infection is unknown as yet. Most cases occur in sheep 1½–2 years old or over, after a long incubation period of up to three years. All breeds of sheep are susceptible but those most often affected are Border Leicesters and Half-breds, Suffolk × Half-bred crosses, and Cheviots.

Symptoms—Following a period of almost inapparent muscle tremors over head and neck, intense skin irritation is shown with rubbing and subsequent marked raggedness of the fleece. Rubbing the skin with the fingers causes a pleasurable "scratch-reflex," the sheep nibbling its lips and wagging its tail. Nervous symptoms also occur; the head is carried high, there is peculiar high-stepping action of the front legs when running, and convulsions are induced by fright or excitement. Death follows almost invariably, often after up to six months' illness.

Treatment and *preventive measures* are not yet known. Affected sheep should be isolated at once.

Sheep scab (notifiable) causes similar but more widespread skin irritation; veterinary diagnosis should be sought whenever symptoms resembling either disease are seen.

Orf—A well-known disease causing pustules, ulceration, and scab formation on the skin, usually of the lips and mouth, teats and udder, coronet of the feet, also the genitalia. The causal virus is long-lived in the dried scabs. Lambs up to one year old are more commonly affected; sucklers may die from inability to suck, but older sheep usually recover and remain immune for about 6 months.

Treatment—Various antibiotics and antiseptic ointments help to prevent secondary infections by bacteria.

Prevention—Sheep over 3 months old may be vaccinated; this prevents severe disease from occurring during the next 6 months.

N.B.—Humans can contract this disease and workers should take hygienic precautions when handling affected sheep or using the live vaccine.

Lambing Sickness—This resembles milk-fever in cattle, i.e., the level of blood calcium falls below normal, but the condition is more rapidly fatal if not treated early.

Symptoms—It may occur after lambing, or before when pregnant ewes are exposed to exertion and fatigue, e.g., over-driving, or transport. A brief period of unsteady gait, a dazed appearance, or excitement, is rapidly followed by stiffness of the limbs, coma and death. Symptoms may easily be mistaken for louping ill, and may resemble pregnancy toxaemia (except that this is usually associated with inadequate exercise).

Treatment—Injections of calcium salts are effective; addition of glucose is also useful to counteract any tendency to pregnancy toxaemia. Careful inflation of the udder also remains an effective cure.

Pregnancy Toxaemia (twin-lamb disease)—In-lamb ewes are affected during late pregnancy when their diet during the previous 2–3 months has been inadequate for the demands of the growing foetuses (especially when twins or triplets are present). Ewes are often in fat condition, but either are short of readily available carbohydrates or have suffered sudden deprivation of food, e.g., as in sudden inclement weather. Lack of exercise may be a contributory factor.

Symptoms—Dullness, slow or staggering gait, either unusually low or high head position, possibly blindness. Temperature is normal, and the condition remains unchanged for some days, although the sheep may be unable to rise. Unless ewes lamb within a few days, or are treated, mortality is heavy. Unlike "lambing-sickness," pregnancy toxaemia does not occur after lambing.

Treatment—Injections of glucose solutions and dosage with glycerine are not always successful. Caesarean operation is helpful if not delayed. The flock should be given concentrate foods and good quality hay. During the last 2–3 months of pregnancy a rising level of nutrition is essential.

Pining (Vinquish)—This describes the progressive loss of weight, dullness, anaemia and poor fleece condition caused by deficiency of cobalt in the soil. (Similar changes

accompany infestations with intestinal or stomach worms). On certain areas, some bordering on granite moorlands, soil lacks cobalt; Scotland, Ireland, North England and some southern counties are affected.

Symptoms are more noticeable in growing lambs soon after weaning. Cobalt is essential for correct rumen digestive processes. Emaciation typically progresses to weakness and inability to rise, but in cases of less deficiency there may be only general unthriftiness. *Diagnosis* may be confirmed by analyses of soil or herbage, also by the obvious response of affected sheep to treatment.

Treatment—Cobalt salts may be administered in several ways: (1) weekly dosage by mouth, (2) mineral licks and mixtures containing cobalt salts, in sheltered boxes at pasture, (3) top-dressing fields every other year with 2 lb. per acre cobalt salts, often incorporated in superphosphate for ease of application.

Treatment for parasitic gastro-enteritis is usually necessary.

Swayback—Lambs may be affected at birth or when 2–6 weeks old. All breeds are susceptible. The condition is widely but irregularly distributed throughout Great Britain. The exact cause is not known but copper deficiency in the diet is a contributory factor.

Symptoms—These vary from complete inability to stand or walk, to slight weakness in the hind quarters, apparent when lambs are hurried. Some lambs are blind. Severe cases die, mild ones recover. Ewes are unaffected.

Treatment—This is useless.

Prevention—Ewes in affected flocks should have access to copper salts, either in mineral licks or in concentrate foods or in worm medicines, during pregnancy.

EXTERNAL PARASITES

Ticks—The common sheep tick (*Ixodes ricinus*) prevails in Great Britain (with other types occurring only locally), e.g., on rough pastures in Scotland, North England, Pennines, North Wales, Cornwall and Devon. Infestations are not maintained in the absence of suitable ground cover, in which ticks spend much of their lives. Their importance lies partly in the skin irritation they cause, especially in young stock, but more by their function as carriers of disease,

e.g., tick-borne fever, louping ill (see notes on these diseases), also:—

Pyaemia—Tick bites inoculate bacterial infection into lambs soon after birth with resulting generalised abscess formations in any part of the body. Symptoms may resemble joint ill.

Treatment—Antibiotic injections may help in less severe cases but are seldom applied early enough.

Prevention—Emulsions containing gammexane or other "persistent" type insecticide should be applied to lambs, or newly born lambs can be dusted with derris powder. Regular sheep dipping is essential to control ticks. "Persistent" dips have replaced the more poisonous arsenical preparations, as protection from one dipping may last three or more weeks. Lambing of hill flocks coincides with the spring flush of ticks, and dipping during the last week of pregnancy is least harmful in such cases.

Lice and Keds—These cause skin irritation, ragged fleeces, and possibly loss of weight. Persistent dips are again effective, especially those containing either DDT or dieldrin, which are also used to protect against fly-strike. Late autumn dipping prevents these parasites from aggravating any tendency to unthriftiness caused by poorer winter diets.

Blow Fly Strike—Blow flies are most active from late May until the end of September, especially during warm, muggy weather. Shelter of woods, hedges and long herbage favours survival of flies. Blow flies are attracted to sheep by odours resulting from soiling of the fleece, e.g., around the breech after diarrhoea has occurred. Flies lay eggs around such areas; maggots hatch in about 12 hours and feed on the sheep's skin for 2–3 days, then drop off to pupate in the ground. Further flies are attracted by the smell of the first hatch of maggots, and a sheep may soon be eaten to death.

Treatment—Daily inspection of sheep permits early dressing of affected animals, preferably with non-irritant fly-dressings which may include DDT and gammexane.

Prevention—Diarrhoea caused by parasitic gastro-enteritis can be avoided by appropriate treatments against worms. Rich feeding should be limited. These precautions reduce

attraction to flies. "Crutching," viz., shearing of wool from the breech and tail areas, and "dagging," i.e., clipping of soiled wool, also assist. Sheep penned closely for dosing or foot-paring should be released as soon as possible.

Persistent dips, e.g., DDT, have commonly replaced the more poisonous arsenical mixtures, and offer protection for at least 6 weeks, except under very wet weather conditions.

DISEASES OF PIGS

Anthrax, Swine Fever, Foot and Mouth Disease and Atrophic Rhinitis have been dealt with under Notifiable Diseases.

Diagnosis of pig diseases is seldom straightforward since similar symptoms may occur in a variety of conditions. Expert veterinary post-mortem examinations are advisable on fresh carcases.

Sudden deaths of pigs should always be fully investigated by a veterinary surgeon—either Anthrax or Swine Fever might be the cause.

Damp, cold, unhygienic houses influence the susceptibility to disease more so in pigs than most other farm animals.

Swine Erysipelas—The bacteria which produce this disease also live in the soil. *Sheep* can also be affected (lameness, following use of dirty dipping baths), and turkeys more rarely so. "Erysipeloid" occurs in humans. Erysipelas is met all over Great Britain but is more prevalent in the eastern counties and Fen district, and more frequent during the summer. Pigs of all ages are susceptible but more especially stores and fatteners.

Symptoms—Very acute disease causes rapid death without typical symptoms. Less acute cases show high fever, poor appetite, staggering gait, diarrhoea or constipation. Typical reddish areas develop on the skin ("diamond skin") in some cases. Swollen limb joints may cause permanent lameness. Chronic disease affects the heart valves; often a single fattening or older pig suddenly dies due to heart failure, with extensive "growths" on the heart valves. Numerous deaths (up to 80 per cent.) occur during severe epidemics, but after milder infections most pigs recover.

Treatment—Penicillin and antiserum injections are effective.

Prevention—Vaccination affords immunity up to 12 months'

duration. During outbreaks, antiserum may be inoculated into other pigs on the premises.

Pig Paratyphoid—Bacteria of the food-poisoning group, *Salmonella cholerae-suis*, cause acute fatal disease, often closely resembling swine fever, in piglets (i.e., 3–10 weeks old), usually less severe in older pigs but often deaths result subsequent to a period of unthriftiness. Symptoms and losses are aggravated by unhygienic and cold houses.

Symptoms may include fever (106° F.), purple discoloration of the ears, muzzle and limbs, and death within a few days. Less severe infection is accompanied by poor appetite, diarrhoea, with loss of weight and a tucked-up appearance. Pneumonia and skin scabs may also occur. Generally, paratyphoid spreads less rapidly than swine fever.

Treatment—Sulphonamides, nitrofurans and antibiotics help to limit losses. More rapid control follows slaughter of chronically affected pigs, and early disposal of others suitable for the butcher. Thorough cleaning and disinfection of the houses should precede re-stocking.

Prevention—Isolation of purchased pigs for 28 days reduces risk of introducing infection by carrier animals.

Necrotic Enteritis is a chronic disease of the bowel which leads to unthriftiness and obvious stunting of growth. Intermittent diarrhoea may occur. Causes are not always known; it may follow an earlier illness or digestive disorder, or result from deficiency of vitamin B.

Treatment—Not economic in bad cases. Drugs used for pig paratyphoid may be helpful, but prevention by good husbandry is the best long-term measure.

Gastro-enteritis—Inflammation of the stomach and intestines is due to various causes. Pigs of different ages are susceptible, more commonly sucklers about 2–3 weeks old, and weaners. *Bacterium coli* is one known specific cause and others are probable. Intestinal worms, coccidiosis, and anaemia are some other common causes.

Symptoms—Mainly diarrhoea, with death within a few days, or chronic illness accompanied by unthriftiness. Some pigs recover.

Treatment—Depends on the diagnosis. Antibiotics or sulphonamide drugs cure some cases. Dosage for worms, or with iron salts, may be required. Cold, damp flooring is

especially prone to initiate enteritis in young pigs which have not developed belly fat.

Pneumonia—Inflammation of the lungs can be due to bacterial or virus infection, also be started by lungworm infestation. Again, unsuitable housing predisposes to this condition.

Symptoms—Acute pneumonia causes fever, panting respirations, and death within a few days. *Virus pneumonia* is less commonly fatal. Piglets aged 2–3 weeks may be affected with temporary diarrhoea, seldom fever, followed by a characteristic cough. Weaner pigs may be first affected on introduction to infected stock in the fattening house. Affected pigs maintain appetite but thrive less well, although many ultimately fatten, perhaps 2–4 weeks later than normal.

Treatments include antiserum injections for some types, also antibiotics.

Prevention—Warm, draught-free pens and good feeding reduce losses due to any form of pneumonia. Virus infection can be transmitted by apparently healthy sows to their newly born litters. Such sows are best slaughtered, and only healthy sows used for breeding, as judged by their production of healthy litters. Outdoor farrowing arks limit the spread of any infectious pneumonia.

Lungworms—Pigs show the characteristic husky cough. Earthworms carry the eggs, and pig infestation can be prevented by rearing on hard-floor pens. Use of permanent pastures should be avoided.

Oedema Disease (bowel or stomach oedema)—Pigs of any age may suffer, but this condition is more common in those 10–16 weeks of age. Research suggests that symptoms are the result of body reaction to toxins (poisons) released in the bowel by large numbers of *Bacterium coli*. Digestive disorders may or may not predispose, e.g., sudden changes of diet.

Symptoms—None may occur, one or two pigs being found dead when normal at the previous feeding. Eyelids may be swollen, appetite lost, and staggering and paralysis of the limbs may follow. Death takes place within 1–2 days, but some pigs recover with treatment. There is seldom any fever. Various internal organs are affected.

Treatment—Specific drugs cure many cases if treated early. Purgation, then a light diet for 3–7 days, also assist. Antiserum inoculations may be helpful sometimes.

Mastitis—Onset is sudden, within 6–48 hours of farrowing.

Symptoms—One or more glands of the udder are hot, swollen and painful, and the sow prevents her piglets from suckling. The discharge is yellow, with clots, and may become purulent.

Treatment—*Bacterium coli* is a common infection and requires appropriate drugs and antiserum injections.

N.B.—*Post-farrowing fever* can also result in hardening of the udder, with lack of appetite and high fever. Many treatments are available but must be commenced soon.

Both conditions starve the piglets and artificial rearing may be essential.

Piglet anaemia—Piglets are born with only a limited supply of iron salts in the body, which is insufficient for the increasing demands of rapid growth during 3–8 weeks of age and onwards. Since sow's milk cannot supply enough, iron salts must either be administered or piglets allowed access to turf or other green food. The third week of life is most critical, when the low iron level in the blood produces the characteristic paleness of the normally pink membranes inside the eyelids and mouth. Diarrhoea sometimes occurs, whitish-yellow in colour. Otherwise, piglets at first continue to thrive but fall back after a few weeks.

Treatment—Preventive dosage (or injection) of iron and copper salts is advisable when 1–3 days old, repeated at 10–14 days. More frequent dosage is required when anaemia has developed. (Copper assists in preventing anaemia.) Iron salts in syrup, smeared on the udder, are also effective but messy and tend to irritate the udder.

N.B.—Symptoms alone are inadequate for conclusive diagnosis; blood tests or post-mortem examinations will differentiate iron anaemia from other diseases.

No benefit ensues by increasing the iron salts in the diet of the sow beyond her normal requirements; the surplus is merely excreted in the dung, not passed on in the milk.

Mineral and Vitamin Deficiencies—Pigs at pasture or having access to green food, are unlikely to suffer from deficiency diseases. Many of the common mixtures of

cereals are low in some vitamins, notably A and D, but these can be provided by either stabilised cod-liver oil, synthetic vitamin mixtures, or by feeding milk products. Deficiencies are more likely on a diet consisting mainly of boiled swill.

Symptoms are seldom so characteristic as to afford precise diagnosis, since bacterial infections quickly add further changes. Signs can include unthriftiness, diarrhoea, scurfy skin, lameness (e.g., rickets), paralysis, " fits," and infertility.

Prevention—Vitamins A and D should be included in the rations, also, either green food, dried grass meal, or dried brewers' yeast. Animal protein should also be given, e.g., fish meal or meat and bone meal, or milk products. Antibiotic residues supply vitamin B_{12}.

Calcium, phosphorus, and common salt are required and are partly provided by the usual ingredients of pig foods.

Excess supplements, of either minerals or vitamins, can be harmful.

Skin Diseases—Mange mites and lice commonly cause scabby, dirty skins, but skin disease often indicates unthriftiness due to internal disorders, e.g., worms, necrotic enteritis, or dietary errors. *Ad lib.* dry feeding may cause a rash over the whole body, attributed to excess calcium in the diet and remedied by feeding additional zinc salts. Vitamin deficiency is another possible cause, but the necessary vitamins B are generally adequately provided by the cereals in the diet (escept for B_{12}).

Mange and lice can be controlled by applications to the skin of persistent insecticides, e.g., gammexane, repeated 2–3 times at fortnightly intervals if necessary. " Pig oil " kills lice. Both types of parasite result in irritation, restlessness and skin rashes. Lice spread over the whole body. Mange first shows on the head, face and ears, also hind-legs, but may spread further in severe cases, causing an offensive smell. Neither parasite lives for long away from the pigs' bodies. Thorough cleansing of sties and destruction of litter, and three weeks' freedom from pigs, is sufficient.

Nervous Diseases—Symptoms range from slight unsteadiness when walking to severe fits and complete paralysis. Some are due to virus or bacterial infections which specifically affect the brain.

Trembling may be an inherited weakness which causes

shivering symptoms in newly-born piglets, which usually recover in a few weeks.

Deficiency of vitamin A may cause convulsions in severe cases.

Simple digestive disorders may cause a staggering gait.

Correct diagnosis may require detailed examination of brain tissue from very freshly dead pigs, and veterinary advice should always be sought.

N.B.—Swine fever (notifiable disease) also affects the nervous system.

DISEASES OF THE HORSE

In Great Britain, infectious diseases of horses are less important than those physical disabilities which cause unsoundness. These interfere with the function required of the animal, be this the steady pull of a draught horse, the weight-carrying of a hunter, or the speed of a thoroughbred.

Detection and assessment of physical disorders requires knowledge of the normal structure and behaviour of a horse. In this, an observant owner can assist a veterinary surgeon by resting a horse immediately abnormal changes occur and before they progress to a severe stage requiring prolonged treatment, sometimes with unsatisfactory conclusion. When buying a horse, it is preferable to pass to a veterinary surgeon the responsibility for detecting defects and certifying soundness.

Disabilities of feet and limbs include temporary lameness due to minor injuries. Picked-up stones and nails, corns and bruises of the sole, and mild laminitis are possible causes. Laminitis (" fever in the feet ") results from body reaction to digestive disorders usually caused by overfeeding rich foods; permanent damage to the shape of the foot and its inner structure may follow. More serious malformations of foot and limb bones include navicular disease, ringbone, sidebone and bone-spavin; these, in a stallion, debar his licensing.

Sprains of tendons, and wounds, may heal, but permanent disability can follow if damage is severe, e.g., when tendon sheaths remain thickened, or infection spreads into limb joints.

Symptoms—A horse *lame in front*, nods down his head when the sound leg is put to the ground, jerking the head upwards

when the lame leg is put down (in an attempt to ease the weight off that limb).

Hind-limb lameness is best seen as a horse is led away from the observer; the hip on the lame side will be carried higher than the sound side.

Slight lameness or stiffness may only be obvious immediately the horse is moved after a period of rest, or when turning round.

Veterinary advice should be sought. Rest from work is an essential part of treatment.

Cracked-heels and Grease—Both conditions are more common in winter than summer; " grease " more often affects heavy draught horses than clean-legged breeds. Dirty stabling, and failure to dry-off legs when wet or muddy, predisposes to skin chapping, which leads to cracked heels. Thereafter, infection may enter and cause " grease." Excessive sweating, as in hunters and racehorses, should be rubbed dry, or bandaged, after work, and not be allowed to evaporate. Washing with soap and water can be harmful. Neither condition is contagious.

Symptoms in cracked-heels are first seen as heat, and swelling of the heels, progressing to skin cracking. Lameness present on first moving may pass off with exercise.

Treatment—Poultices (e.g., kaolin type) may be used to reduce swelling, but must not remain on longer than 24–48 hours. Any discharges from the cracks must be dried up by using astringent lotions (e.g., " White Lotion "), thereafter antiseptic ointments should be rubbed in, or carbolised oil (5 per cent. carbolic acid in rape oil) applied and soft bandages put on. " White Lotion " contains lead and is poisonous.

Grease—First shows as intolerable itching, the legs being rubbed and stamped, and becoming swollen. This progresses to excess foul-smelling discharge and marked thickening of the leg, pain and stiffness. If unattended, ulceration may occur.

Treatment is satisfactory if commenced at first sign of grease. Hair must be clipped short, and poultices applied twice daily for 2–3 days. The discharge should be cleaned off before renewing each poultice.

" White Lotion " may then be used, or more drastic astringent mixtures on the advice of the veterinary surgeon.

Regular, gentle exercise must be the first introduction to work after recovery is complete.

Itchy Legs—This condition is seldom seen in Great Britain. It is caused by mange mites infesting the pasterns and seldom higher than hocks or knees.

Symptoms—Are those of obvious skin irritation, producing stamping and rubbing, even biting, of the affected limbs. Extreme cases may make a horse vicious.

Treatment—Persistent insecticides, such as DDT or gammexane, may require second application after one week. The emulsion more readily contacts the skin after clipping the hair short and previously washing the skin with soap and water.

Grooming kit should be washed in soap and water, may then be washed with insecticide emulsion and dried thoroughly in sunlight.

Lymphangitis (Monday Morning Leg, Big Leg, etc.). This condition affects heavy draught horses when the full feeding given during hard work is continued during the days when not working.

Symptoms—The horse appears in great pain, probably sweating profusely. One hind limb, rarely a fore limb, is greatly swollen, hot and tender, and no weight is placed on it. Hand pressure inside the thigh causes obvious pain in the effort to draw away the limb. The horse's temperature is very high, the pulse rapid and full.

Treatment—Full doses of purgative medicines, and diuretics to promote kidney function, should be followed by only a light diet of bran mashes and good hay. (Similar rations should also replace the usual corn feed during the week-end rest.) Hot fomentations to the leg ease the pain and aid reduction of the swelling. Liniments and massage are not helpful and may be harmful. Quick-acting purgatives may be injected by a veterinary surgeon to hasten recovery, which, in bad cases, may otherwise take a few days. Light exercise assists.

Certain horses are more prone to this condition, and subsequent attacks may become progressively more difficult to cure.

Colic—This is, strictly speaking, " pain in the colon " (large bowel), but is commonly used to describe any ab-

dominal pain. The several types of colic require different treatments. The two most common forms are *spasmodic* and *flatulent* (" windy ") colic.

Symptoms—Spasmodic colic describes the severe attacks of pain which cause a horse to be restless, getting up and down continually, and throwing itself about or rolling. Between attacks the animal stands quietly and its sweat dries off. If dung is passed at all, it is in the shape of hard, angular pellets.

This type of colic may be caused by hunger followed by excess quantity of indigestible food, or feeding or watering immediately after exertion, or exposing a horse to cold and wet whilst sweating. Watering *during* work is necessary and beneficial.

Treatment—A sedative mixture, usually containing chloral hydrate (well diluted), should be given to relieve the painful spasms until veterinary help is available.

Flatulent colic is caused by excess gas in the intestines or stomach, due to fermentation of food, e.g., gorging on succulent green food or excess corn. Indigestion caused by full feeding of a tired, hungry animal has a similar effect.

Symptoms—Pain is again shown, usually more continuously but less violent. The abdomen is distended by gas and tense, the horse may again roll (but more carefully), and breathing may be distressed by pressure of intestines on the diaphragm. Gas in the stomach itself may be fatal if not relieved quickly.

Treatment—A colic drench containing turpentine and raw linseed oil helps to allay gas production, and bowel movement may be stimulated by repeated enemas of not more than one quart of warm (not *hot*) soapy water. Light walking exercise every half-hour is helpful. Quick-acting drugs can be injected by a veterinary surgeon who can also pass a stomach tube in serious cases to ease gas in the stomach.

Unlike in emergency relief of bloat in cattle, horses should not be punctured to release gas except under supervision of a veterinary surgeon.

Any case of colic requires laxative feeding and careful nursing for some days after recovery.

Sore Backs and Collar Galls—These and sore shoulders are caused either by friction or pressure resulting from

badly fitting or ill-adjusted harness or saddles. Young horses freshly up from grass when first put into the collar may have their shoulders " scalded " by the sweat and the chafing of the collar on tender skin.

Galled necks result from either friction, as when the collar is too long, and rocks instead of remaining firm, or from pressure due to lumpy stuffing of the collar. Either condition may be aggravated by either too high or too low adjustment of the draft.

Saddle galls are similar sores caused by pressure of lumpy badly-fitting saddles; over the withers extreme pressure can damage the underlying bone spines; neither harness pad nor riding saddles must bear on the backbone, only on the back muscles alongside the mid-line.

Sit-fasts may follow from galls, and are areas of dead skin in the centres of sores (only treated by surgical removal).

Girth galls, which occur just behind the point of the elbow, are caused usually when skin wrinkles (after tightening of the girth) are not smoothed out. Again, they are more common in horses fresh from grass. The chafing can be prevented by slipping the girth through a piece of inner tubing of a car or motor cycle tyre.

Treatment—Actual sores can be dressed with " White Lotion " (this contains lead and is poisonous). When dried up, the sores can be treated with zinc ointment, provided the horse is resting—chafing over the ointment during work will cause loss of hair. Ample rest is essential.

Preventive measures—Avoid use of ill-fitting harness or saddlery. Caked sweat and dirt aggravate the risk, and saddles and harness must be kept clean. Sweat should be washed off the shoulders of " green " horses, using cold, salty water; when dried, surgical spirit dabbed on twice daily will help to harden the skin.

Strangles—This is a contagious disease which affects chiefly young horses, occasionally older animals. Virus infection is complicated by streptoccal bacteria to cause the typical symptoms.

Symptoms—High temperature, coughing, and discharge from the nostrils is followed by swelling of the glands under the jaw. Fever causes thirst, also inappetence (aggravated by the sore throat). Infection may cause abscesses to form in

internal organs. The disease may spread rapidly throughout young horses in a stable.

Treatment—Sulphonamide drugs given early in the disease are effective in preventing the general illness which often occurred before these drugs were available. Antibiotics are also used. The animal should be isolated, preferably in an airy loose-box, fed lightly on sloppy foods (e.g., gruels) and greenstuff, with water *ad lib.*

Broken Wind—This term describes the double lift of the flank seen during expiration of air. It is often accompanied by a cough, sometimes by persistent nasal discharges. It is caused by the extra effort required to expel air due to the breakdown of normal elasticity of the lungs and the abnormality often follows return to work too soon after lung disease, e.g., bronchitis or strangles, and is more likely in fat horses and those in soft condition.

Worms and Debility—Redworms are the small roundworms which inhabit the large bowel and are a major cause of general unthriftiness, especially in young animals and those penned on insufficient pasturage. Loose dung, even diarrhoea, and anaemia, are other symptoms. Diagnosis may be confirmed by laboratory tests of fresh dung samples.

Treatment—Phenothiazine, or piperazine drugs, are effective. Many horses take these readily on a little damped corn. Dosage can be administered as one full dose or spread over a period of a few days.

Prevention—Overstocking and overgrazing should be avoided. Mares should be regularly treated to prevent the accumulation of worm eggs on pastures, to which their foals would be more susceptible. Cross-grazing with sheep or cattle helps to reduce this contamination as these stock are not affected by the horse redworms.

Debility can also be caused by faulty chewing of food due to "teething," or to wear producing sharp edges to the molar teeth (which must then be rasped carefully), or to decayed teeth in old horses. Old age generally results in poorer condition, and inability to work normally without exhaustion. Starvation also is responsible during dry summers or prolonged winters. Careful feeding on easily

digested and highly nutritious foods may restore normal condition, but introduction to light work must be gradual.

TEMPERATURES

TABLE 55: NORMAL TEMPERATURES OF LIVESTOCK

Cattle	average	101° F. (range, 101·8–102·4° F.)
Horses	,,	100·5° F. (range, 100·4–100·8° F.)
Sheep and Goats	,,	102° F. (range, 101·5–105·8° F.)
Pigs	,,	103° F. (range, 101–105° F.)
Dogs	,,	101° F. (range, 101–102° F.)

Young animals usually show higher temperatures than adults. Sheep in full fleece, and lactating cows also show higher temperatures.

DISEASES OF POULTRY

DISEASES of poultry, like those of other animals, can be divided into two main groups:—

1. Specific diseases, caused by a distinct or specific parasite, germ or virus and which are infectious or contagious.

2. Non-specific diseases which occur either as constitutional disturbances of individual birds, or may be due to some factor in management, nutrition or breeding.

SPECIFIC DISEASES

Divisible into bacterial, virus, protozoan, internal or external parasites.

BACTERIAL

B.W.D. (Pullorum disease) caused by a bacterium of the salmonella group (*S. pullorum*) may give rise to losses of from 20 to 80 per cent. Symptoms are not characteristic, and infected chicks may simply be found dead or dying within a few hours of showing lack of appetite, ruffed feathers, and sleepiness. Diarrhoea may or may not be present. Post-mortem lesions are inconsistent and specimens should always be sent to a veterinary laboratory for diagnosis. Chicks which survive an outbreak become carriers, the organism usually being found in the ovary. When these carriers mature, some of their eggs will contain the germ. During incubation the germs multiply with rapidity and when the resultant chicks hatch out they are bathed in a suspension of the germs. As the chicks " dry off," infected down spreads through the incubator by the air currents and infects large numbers of further chicks as they hatch. In turn these infected chicks transmit the disease to other chicks by contamination of food and water while in the brooder house. Control depends on the removal of carriers from the breeding flock by blood testing. This means taking a sample from the wing vein and sending the tube to a laboratory, or by using the rapid method which can be carried out on the farm. Under the P.S.I.P. testing is carried out by the rapid method free of charge. Details can be obtained from any veterinary

laboratory, from a veterinary surgeon or Poultry Advisory Officer.

After removal of carriers, disinfection should be carried out and the remaining birds retested at monthly intervals until no further carriers are found. Control of the disease in incubators and the brooder house will be dealt with under the section on hygiene.

The drug furazolidone is highly effective in the treatment and prevention of B.W.D. in chicks. The drug is also a valuable adjunct to blood testing for the routine treatment of " infected " flocks after carriers have been removed. Details regarding dosage should be obtained from the manufacturers.

Salmonellosis—This term is used to describe outbreaks of disease in chicks caused by organisms of the salmonella group other than B.W.D and fowl typhoid. Some 30 organisms in this group are known to cause disease in chicks in this country.

The course of the disease is similar to that already described for B.W.D. Survivors again remain as carriers, usually harbouring the organism in the bowel wall, eggs laid by these carriers become contaminated on the outside of the shell with infected droppings and under incubator conditions the organisms penetrate the shell and infect the embryo. From then on the disease spreads in the same way as B.W.D. A measure of control can be obtained by collecting eggs frequently, using clean nest box litter and good egg storage conditions, etc. Dirty eggs should be dry-cleaned or dipped in germicidal solutions.

Vermin are carriers of this disease so that every effort should be made to control vermin and to keep food in vermin-proof containers.

In view of the large number of orgnisms which may be responsible, routine blood testing is not generally effective. In certain selected cases where the organism has been definitely identified, special testing can be carried out. Furazolidone as outlined for B.W.D. can also be used for the treatment and prevention of the disease.

Fowl typhoid is caused by *S. gallinarum*. This disease differs from the first two in that losses usually occur in mature birds. The disease is commonest in Wales, S.W. England and the bordering counties and the East Riding of

Yorkshire. The mortality rate may be as high as 70 or 80 per cent.

Individual birds show lack of appetite, profuse yellowish diarrhoea, paleness of the head and die within 48 hours of first appearing ill. On post-mortem examination the liver will be found to be bronze-green in colour and the lungs congested and dirty brown. Furazolidone is again a highly effective treatment for this disease but must be accompanied by sound hygiene and if possible treated birds should be moved to clean ground, the carcases of infected birds must be incinerated or buried in quick lime. Houses and equipment should be thoroughly disinfected. Blood testing should then be carried out and carriers removed from the flock. The blood test for B.W.D. is equally effective for this disease. New forms of vaccines are at present under trial.

Tuberculosis is caused by the avian strain of the tubercle bacillus, which is also responsible for tuberculosis in pigs. For this reason, pigs and poultry should not be kept in close contact. Cattle can also become infected with the avian strain but the disease is not progressive, although it may give rise to doubtful reactions to the tuberculin test in cattle. Infection occurs from the ingestion of food and water contaminated with droppings of infected birds. As in other animals, the disease is chronic and may be well established before symptoms are seen. Infected birds usually become emaciated, paleness of the head is common and there is frequently lameness of one leg. On post-mortem examination tubercles are found in the liver, spleen, intestines and bone marrow. No treatment is of value and it is usually most economical to slaughter the affected pens, burn or bury the carcases and carry out thorough disinfection. With valuable flocks infected birds can be detected by means of the tuberculin test which is carried out by injecting tuberculin into the wattle.

Fowl cholera is a highly infectious disease, which may cause losses of up to 100 per cent. It is caused by a bacterium *Pasteurella aviscepticus*. The disease is usually rapid and few symptoms are observed. Birds are dull and the head parts congested and purple in colour. There is a profuse green diarrhoea. Post-mortem examination is inconclusive and requires bacteriological confirmation. Treatment by the

intramuscular injection of terramycin in oil has recently been shown to be effective. Carcases of dead birds should be burned or buried and disinfection carried out. A chronic form of the disease occasionally occurs in this country in which the only obvious symptom is a swelling of the wattles. Mortality with this type is low.

Infectious arthritis—This disease is sometimes seen in young stock causing lameness with hock-joint swelling. It results from infection with staphyloccal germs in small wounds of the feet and legs, usually caused by wire, thistles, glass, etc. Removal of the birds to fresh pens and thorough disinfection results in the condition clearing up. The disease responds to injections with penicillin.

Infectious coryza (Contagious catarrh)—One form of this very common disease is caused by the bacterium *Haemophilus gallinarum*. Outbreaks vary in their severity and although losses are usually few, there is frequently severe interference with growth and egg production. Infected birds usually show discharge from nostrils and eyes which dries up in the form of crusts. The condition is most prevalent when ventilation is poor or where there is overcrowding, malnutrition and other debilitating conditions. Infection does not appear to produce immunity and survivors are frequently carriers and set up further outbreaks.

Prevention consists of improvements in management and hygiene and an adequate supply of vitamin A should be fed. Affected birds should be isolated and disinfection carried out. Sulphonamide drugs, e.g., sulphathiazole and sulphamezathine are found to be effective against this type of coryza. The addition of disinfectants to the drinking water, such as Lugol's iodine at the rate of one teaspoonful per gallon helps to prevent the spread of infection.

Chronic respiratory disease—This is a much more serious disease and although the exact cause is uncertain, pleuro-pneumonia-like organisms (P.P.L.O.) are usually involved. Losses may be heavy in young stock but the main economic loss arises from slower growth, interference with egg production and poor carcase quality. Survivors become carriers and it is believed that egg transmission may occur. Symptoms resemble those of coryza but are more severe, face swelling is common and infection may extend to the air-sacs.

Treatment by the high-level feeding of antibiotics gives satisfactory results on occasions.

VIRUS DISEASES

Fowl Pox, also known as chicken pox, avian diphtheria or roup. This is a contagious disease which exists in two forms. The first type is shown by the occurrence of small watery blisters on the comb, wattles and round the eyes. These blisters dry up into brownish crusts which eventually run together to form large wart-like growths. The second type is shown by the occurrence of yellow diphtheritic membranes covering the tongue, sides and roof of the mouth, and throat.

Infection is usually spread by contamination of small wounds, but over-crowding, insanitary conditions and external parasites all contribute to the rapid spread of the disease. Although a large number of birds may become infected, the death rate may not be high, but many of the affected birds may have to be destroyed from loss of condition. One or both forms of the disease may be present in the same bird or in the same flock. Provided the disease is observed before many birds are affected, the most economic procedure is to destroy affected birds, carry out thorough disinfection and vaccinate the healthy ones. Vaccination is carried out by brushing a drop or two of the vaccine on to a small area of the thigh from which a few feathers have been removed. If vaccination is successful, the area will be markedly swollen in 4–5 days. After vaccination 14 days must elapse before immunity is produced; during this time the birds must be protected from further infection. Immunity lasts for about 4–6 months.

Fowl Pest—This is a collective term used for legislative purposes and includes the two diseases—Newcastle disease and fowl plague.

These are the only two poultry diseases in Great Britain which must be notified by law and in which there is compulsory slaughter of all infected flocks.

Newcastle disease occurs in two forms, either an acute, highly infectious disease with a mortality rate as high as 90–100 per cent. or as a sub-acute or mild form in which losses may be negligible but there is a marked drop or cessa-

tion in egg production, laying of soft or shell-less eggs, nervous symptoms and "colds."

The present epidemic started in 1947 and originated from infected table poultry imported from Europe. The disease mainly occurs in fowls, but outbreaks have been reported in pigeons and turkeys; ducks and geese are fairly resistant but may be capable of spreading infection to in-contact stock. In acute outbreaks, death usually occurs within 2–3 days of the first appearance of symptoms of frothy yellow diarrhoea, purplish congestion of the head and comb and a high-pitched rattling cough. Nervous symptoms may occur with twitching of the head and limbs and twisting of the head backwards or downwards. Any owner suspecting this disease, must immediately notify the nearest police station. If the disease is confirmed, there is compulsory slaughter of all birds and compensation for the non-affected birds. Disinfection of the premises is then carried out under supervision.

There are a number of other restrictions and orders regarding the movement of poultry, boiling of swill, disinfection of crates and utensils, etc. Poultry farmers should make themselves acquained with their obligations under the Fowl Pest Order, copies of which can be obtained from the nearest police station, or direct from the Ministry of Agriculture.

In view of the fact that the disease is compulsorily notifiable, there is little point in describing its other features. Many outbreaks result from birds having access to infected material such as swill, hotel waste, etc., containing offal of infected poultry. Under the Swill Boiling Order, all swill must be boiled before being fed to poultry.

Infectious Laryngo Tracheitis—This is also an infectious disease affecting the respiratory tract. Outbreaks mainly originate from carrier birds, i.e., birds which have recovered from a previous attack. Infection can also be carried on attendants' feet, clothes, etc., and on appliances. The disease usually occurs suddenly with symptoms of coughing and sneezing in which the bird extends its neck fully and makes a prolonged inspiration through the wide-open beak. Breathing is accompanied by rattling and clots of blood may be coughed up and be seen on the walls of the house. The death rate may be as high as 80 per cent. On post-mortem examination, clots of blood or cheesy material may be seen

obstructing the windpipe. There is no known treatment and affected birds should be slaughtered and all contacts isolated. Thorough disinfection of the premises and utensils must be carried out.

Other virus diseases are known to occur but are relatively uncommon compared with those described.

PROTOZOAN DISEASES

Coccidiosis—Probably the heaviest cause of loss in chick rearing, caused by a small parasite of the protozoan group known as a Coccidium. There are two main types of the disease; the acute form (caecal coccidiosis) which occurs mainly in young chicks during the first few weeks of life causing severe losses, often as high as 50 per cent. of the affected hatch.

The second type known as intestinal coccidiosis is more chronic and occurs in older chicks of 3–4 months of age. Losses are not so heavy but there is severe emaciation and loss of condition.

In the caecal form, death is due to acute hemorrhage into the caecal tubes. Affected chicks may pass blood or blood-stained droppings. On examination, the caecal tubes will be found filled with blood or blood clot. In the intestinal form there is a persistent diarrhoea due to chronic inflammation of the small intestine.

Coccidia occur in a wide range of animals but each animal has its own particular species of the parasite. For example, the coccidium of the rabbit does not affect the fowl and vice versa—in fact coccidia of the chicken are quite distinct from those causing disease in turkeys and geese. The coccidium has a complicated life history the most important factor being that the parasite cannot infect other birds immediately it is passed out in the droppings and must spend a certain part of its time on the ground outside the host. This period depends on certain conditions of warmth and moisture and may not be less than 48 hours. On the other hand, the parasite may remain alive outside the body for as long as 18 months and still be infective.

In controlling the disease, advantage is taken of this fact by preventing chicks from having access to infected droppings. This is done by thorough cleaning of the house, the use of wire floors, movable folds, etc. Damp litter should be

avoided and improvement in ventilation often helps. Overcrowding is also dangerous. The most effective disinfectant for floors, houses and utensils is a 10 per cent. watery solution of household ammonia, but chicks should not be allowed back until the house is free from all traces of ammonia.

A number of drugs are now available for the prevention and treatment of coccidiosis, those in common use in this country being sulphamezathine, sulphaquinoxaline, nitrofurazone and nicarbazin. These drugs are marketed under various trade names and used either in solution for adding to the drinking water or in premix form for mixing in the mash. For details regarding dosage, application should be made to the manufacturers.

Blackhead—This is probably the commonest cause of loss in turkeys. It is caused by a protozoan parasite *Histomona meleagridis*. The exact life history of the parasite is uncertain, but is probably associated with the caecal worm of the fowl. The mortality rate in young turkeys is frequently high and the common symptoms are ruffling of the feathers, loss of appetite and a mustard yellow diarrhoea. On post-mortem examination circular greenish-yellow areas are seen in the liver and the caecal tubes are thickened and ulcerated.

Prevention by hygiene is similar to that outlined for coccidiosis. Young poults should not be reared in contact with older birds or on ground used for other fowls. Various proprietary drugs are available which are of value in the treatment of the disease. Those in common use are 2-amino-5-nitrothiazole, 2-acetylamino-5-nitrothiazole and furazolidone.

FUNGI

Aspergillosis—This is also known as brooder pneumonia and results from chicks inhaling spores of the fungus Aspergillus, which usually occurs in damp or mouldy litter or feeding stuffs. The chicks show symptoms of difficult breathing and on post-mortem cheesy white nodules are found in the lungs and air sacs. There is no known treatment of value. Infected chicks should be killed, thorough disinfection carried out and an attempt made to find and remove the offending material.

Moniliasis—This disease is mainly seen in young turkey poults and is caused by the fungus Candida which causes ulcerated patches in the crop. Losses can be high and often appear to be associated with vitamin deficiencies. No treatment is known. Slaughter and disinfection is so far the most satisfactory method of control.

INTERNAL PARASITES

Most of the larger parasites which are found in or on poultry are only harmful if their numbers are excessive. Damp, dirty and badly ventilated houses and malnutrition all lead to the rapid multiplication of such parasites. Two types of worms infest poultry, round worms and tapeworms.

(1) The large round worm—*Ascaris galli*—about 1½ in.–3 in. long and greyish-white in colour is found in the small intestines. Treatment is carried out with Piperazine compounds a number of which are available under trade names.

(2) The caecal worm—*Heterakis galli*. Small threadlike, greyish-white in colour, about ⅓ in. long and found in the caecal tubes. Treat with phenothiazine, ½–1 gramme per bird.

(3) The gizzard worm—*Amidostomum nodusolum*—occurs in goslings, causing ulceration and haemorrhage of the gizzard wall and may be fatal. Hair-like, white and only ¼ in. long, the worm can only be seen with difficulty adhering to the gizzard wall. Treatment, carbon tetrachloride, 1–2 cc. per bird in capsule.

(4) Tapeworms. Two forms occur in fowls. The small tapeworm, *Davania proglottina*, occurs in the small intestines and is seen as small white specks. The larger tapeworm—*Railletina*—is also found in the small intestines. It is white and up to 3 in. to 4 in. long, showing many segments. Tapeworms are best controlled by the destruction of their intermediate hosts, slugs and snails, by copper sulphate spraying of the runs.

Heavy infestations with worms causes unthriftiness, stunted growth, diarrhoea and anaemia. Prevention mainly depends on improved hygiene, frequent removal of droppings and soiled litter, separate rearing ground for young chicks, use of movable folds, etc. Infected runs should be rested for as long as 12 months.

EXTERNAL PARASITES

As with "worms," heavy infestations usually result from bad management and cause loss of condition, stunted growth and in older birds, a drop in egg production.

The chicken flea is similar to that found in other animals and mainly attacks the lightly feathered parts, under the wings, back of head, etc. Different species of lice are found in different parts of the body—head louse, body louse and wing louse.

The commonest mite is the "Red Mite"—*Dermanyssus gallinae*—which feeds on the bird at night and may cause death by anaemia. Another mite burrows under the skin and roots of the feathers causing inflammation of the skin and loss of feathers. It causes the disease known as "depluming scabies." A third form burrows under the scales of the legs causing them to become swollen and covered by a white chalky deposit and is called "scaley leg."

Treatment for external parasites can be carried out by dusting the birds with powdered sodium fluoride, D.D T., gammexane or similar parasiticides. Nicotine sulphate (40 per cent.) is effective when used as a perch paint. Control, however, mainly depends on disinfecting the house. Perches, nest boxes, etc., where these parasites can hide and breed must be movable and should be dismantled at regular intervals, cleaned, creosoted or dipped in a paraffin emulsion. The walls, floor and ceilings should be similarly treated when "spring cleaned." Lime washes or paints in which D.D.T. or gammexane are incorporated are also valuable. When the house can be made air-tight, gammexane smokes are effective.

NUTRITIONAL DISEASES

Vitamin A—A deficiency of this vitamin will retard growth, and cause the condition known as Nutritional Roup. The eyes show a watery discharge which later becomes a white cheesy deposit in the eye sockets and in the nasal passages. The best sources of vitamin A are fish oils and green foods such as clover and pasture grasses. Vitamin A is rapidly lost on exposure to the air and if fish oils are being used as its source, they must be mixed in the mash not more

than a few hours before use. Fish oils must be stored in air-tight containers. Stabilised vitamin A is commonly used.

Vitamin B—There are a number of vitamins within this group, and a deficiency of several of them cause disease in chicks. The condition known as " curl-toe paralysis " results from a deficiency of riboflavin. In affected chicks the toes are turned inwards and in severe cases chicks may walk on the upper surface of the toes. A deficiency of pantothenic acid (also part of the vitamin B complex) causes chick dermatitis. Small crusty scabs appear at the corners of the beak, and around the eyes. Yeast (3–5 per cent.), dried skim milk, or dried whey are the best sources of vitamin B. The pure vitamins are now mainly used.

Vitamin D—Lack of this vitamin gives rise to rickets. Affected chicks lose the use of their legs, become dejected and unthrifty. The legs bend, the ribs thicken and the beak becomes soft and rubbery. The addition of 1–1½ per cent. cod liver oil or vitamin D_3 usually prevents or cures rickets, but it may also arise as a result of an unbalanced or inadequate supply of calcium and phosphorus in the ration. A lack of direct sunlight also causes rickets.

Vitamin E—Deficiency of this vitamin is thought to be associated with the condition called " crazy chick disease." Affected chicks walk in circles, or backwards, twisting the head back over the body. A deficiency of this vitamin probably results from its destruction by some other constituent in the ration, e.g., rancid oil or excess of cod liver oil. Antioxidants are now used to prevent the loss of vitamin E.

Perosis—Is also known as " hock " disease or " slipped tendon " and is thought to be caused by a deficiency of the mineral manganese, probably associated with a deficiency of choline (vitamin B complex). In affected chicks the large tendons of the legs slip outwards from the hock joint. The leg becomes twisted and the chick walks on its hocks. The addition of 4 oz. of manganese sulphate per ton of food corrects the trouble.

AVIAN LEUCOSIS COMPLEX

Until recently this term was used to describe a group of diseases including fowl paralysis, visceral and ocular lympho-

matosis and various forms of leucosis. These were thought to be different manifestations of the same disease but it is now recognised that they are quite separate entities, caused by different agents and probably unassociated one with another. This group of diseases is the commonest cause of loss in poultry and accounts for nearly 40 per cent. of the mortality in mature poultry. Unfortunately our knowledge of the exact cause and methods of transmission of leucosis is incomplete.

AVIAN LEUCOSIS

There are three forms of leucosis, all are neoplastic or cancerous in nature and consist of the abnormal multiplication and subsequent infiltration and disposition into various organs of different types of immature blood cells. Probably all three types are caused by viruses.

Lymphoid leucosis—This is the commonest type and occurs either in diffuse or discrete form.

In the discrete form there are multiple, white, soft tumour growths, mainly in the liver, spleen, kidneys, heart and lungs. The liver is the most commonly affected and may be three to four times is normal size. The diffuse form is known as "big liver disease." The liver and spleen are greatly enlarged but retain their normal shape, the whole organ being changed to a mottled, greyish-red colour.

Myeloid leucosis—This may also occur in discrete or diffuse form. In the diffuse form the liver and spleen are enlarged, firm, and have a marbled brown appearance. In the discrete type soft chalky tumours occur on the inner surface of the breast bone, along the ribs and in the abdominal cavity.

Erythroleucosis—In this type red cells rather than white cells are involved. The liver and spleen are swollen, cherry red in colour, soft and fragile. Tumour masses do not occur.

Both types (*b*) and (*c*) are transmissible experimentally and are known to be associated with viruses. Lymphoid leucosis appears to be transmissible but the presence of a virus has not yet been proved. In all three types egg transmission probably occurs, although it is felt that in practice this is of less importance than spread of the disease during

brooding. The symptoms of leucosis are variable but it generally occurs in birds from about six months to a year. There is loss of condition, paleness of the head and interference with egg production. Although the course of the disease may be chronic, death may occur suddenly.

FOWL PARALYSIS

This disease, which is also known as neurolymphomatosis, is thought to be a chronic inflammation of the nerves of an infectious nature. There is enlargement of various nerves, particularly those to the wings, legs, chest wall and intestinal tract. In some cases the nerve lesions are accompanied by tumour-like growths of the liver, spleen, kidneys and ovary, etc. This type is known as visceral lymphomatosis and may be confused with lymphoid leucosis. The symptoms depend on the nerve involved but the commonest is paralysis of the legs which starts as a limp followed by a clutching appearance of the foot and finally complete paralysis of one or both legs, drooping wings, twisted neck, difficulty in breathing and impaction of the intestines occur when the nerves associated with these organs are affected. Fowl paralysis usually occurs at between three to six months of age. The exact cause is obscure but it is possibly due to a virus.

Iritis—At one time this condition was known as " ocular lymphomatosis " and thought to be a form of paralysis. It is now thought that the disease is quite separate and that it is possibly infectious in nature although the cause is obscure. The iris of the eye loses its normal colour, takes on a blue-grey shade, while the pupil becomes irregular and slit-like.

Osteopetrosis—This is a somewhat rarer disease, also known as " Marble bone " and was thought to be a part of the same complex. It is now considered to be a separate entity. The cause, like that of iritis, is obscure but it is probably associated with some defect in normal bone metabolism. The disease consists of gross enlargement and thickening of the long bones, mainly those of the shank.

Transmission—Although the exact manner in which both leucosis and fowl paralysis are transmitted is obscure there is strong evidence to suggest that chicks are most susceptible during the early rearing period. As a result it has been shown

that the greater the degree of isolation in which chicks are brooded apart from adult stock, the lower will be the incidence of the disease. At the moment there is no evidence that fowl paralysis is transmitted through the egg. It is known that families vary in their resistance to leucosis and fowl paralysis and that such genetic differences can be used to reduce losses either by mass selection or progeny testing. There is at the moment no known treatment or vaccine for either leucosis or fowl paralysis and no accurate test has yet been developed by which carriers of this disease can be detected.

Pullet Disease (or Blue Comb)—It is an acute disease and usually a large number of birds in a flock become affected at the same time. There is sudden loss of appetite accompanied by whitish diarrhoea and the combs may turn dark blue or purple. The most striking feature is a sudden drop in egg production, sometimes in pullet flocks from 50 per cent. to nil in a few days. Affected birds show a tendency to eat coarse grass or bedding, often leading to crop-binding. As a rule only a few birds die, although there may be a number of culls. The remainder recover spontaneously two or three weeks later.

The disease results from a breakdown of the kidneys and birds which die show disease of the kidneys (nephritis) with deposits of urates on the heart, liver and spleen. This latter condition is known as visceral gout.

The cause of this disease is obscure, and although outbreaks frequently coincide with changes in the feeding, there is no evidence that any ingredient or foodstuff as such can set up the disease. Some workers claim that new wheat is responsible—this theory has found little support. In some respects the disease would appear to be infectious but no infectious agent can be incriminated. Keeping the flock intensively for a few days or restricted to the house helps to prevent crop binding. Mild laxatives such as Epsom or Glauber salts can be given and it has been suggested that the addition of 10 per cent. molasses or other readily available carbohydrate, to a wet mash is helpful. One American worker recommends the addition of 0·5 per cent. potassium chloride to the drinking water. Recently good results have been claimed for the high-level feeding of antibiotics in the treatment of pullet disease.

MISCELLANEOUS DISEASES

Cannibalism and feather pecking—Both these conditions are often associated with some factor in the management, such as overcrowding, lack of trough space, or may even be of nutritional origin, e.g., a deficiency of protein. Once started the condition rapidly becomes a " vice " copied by other birds which are attracted to pecked or bleeding surfaces. Some workers claim that the vice can be treated by increasing the salt content of the diet to 2–2½ per cent. for a few days. The vice can be controlled by " debeaking," e.g., removing the point of the upper beak. " Spectacles," a device which fits through the nostrils and only permits the bird to look downwards, are the most effective control. Injured or pecked birds which invite cannibalism should be isolated immediately and the area dressed with a deterrent such as Stockholm tar.

Impaction of the Crop—This may occur as a symptom in a number of diseases, such as fowl paralysis or pullet disease, but more frequently results from a mechanical cause such as access to long grass, straw, feathers, etc., or consumption of large quantities of bulky foods. It can often be treated by holding the bird head downwards, " kneading " the crop and removing the contents through the beak. Early cases respond to flushing out the crop with water. In advanced impactions surgical removal of the contents through the crop wall may be required. In large flocks single cases are usually culled and treatment is uneconomical. When several birds become affected the diet and management should be investigated, and the grass in the runs kept short.

Vent gleet—This is thought to be a contagious disease spread at mating or by contact with infected nest box litter, etc. It starts with soiled feathers round the vent and the skin of that region is inflamed, swollen and often shows cheesy, white, evil smelling, deposits. A number of birds may be affected with a consequent drop in egg production. Cannibalism may result. Advanced cases should be destroyed and early cases isolated, particular search being made for affected males. The affected part can be treated by swabbing with antiseptic lotions, the cheesy deposits removed and the surface dusted with sulphonilamide powder.

Bumblefoot—Is an abscess in the region of the foot, usually resulting from small wounds caused by glass, wire, small stones, and which become infected with bacteria. The foot becomes obviously swollen, hot and painful and the infection may extend up the shank tendons causing severe lameness. Usually surgical incision of the abscess and removal of the solid pus is necessary. The wound is then packed with gauze soaked or impregnated with an antiseptic and a dressing applied. Except in valuable birds, treatment is uneconomical.

Egg peritonitis—This is one of the commonest conditions met with in the post-mortem examination of poultry. It often results from " internal laying," the yolks passing direct into the abdominal cavity; or as a sequel to " egg-binding." Carriers of B.W.D. and fowl typhoid where there is infection of the ovary are often affected with egg peritonitis. Affected birds have a penguin-like appearance with a swollen abdomen. There is no cure.

Egg binding—This occurs when the oviduct becomes obstructed by a large broken, or misshapen, egg or by the accumulation of abnormal egg material in the oviduct. Affected birds repeatedly visit the nest without laying and will be seen to strain. Prolapse of the vent and oviduct may result, and may be followed by " cannibalism."

In some cases the impacting mass can be removed by inserting a finger through the vent and manipulating the abdomen.

Poisoning is common in poultry, usually as a result of accidental access to carelessly placed rat baits. The commonest are arsenic, phosphorus, and zinc phosphide. All cause sudden death and there is seldom an opportunity to use antidotes.

HYGIENE

Except in the case of the deep or built-up litter method, all poultry houses must be regularly cleaned out and occasionally subjected to a thorough spring cleaning. Bacteria, viruses, worms and other parasites all multiply very rapidly in a dark, dirty and humid atmosphere. Houses should be well ventilated and lighted and so constructed that perches, nest boxes, etc., can be readily removed and do not permanently

harbour dust, dirt and other debris. Dropping boards should be scraped daily and slatted floors similarly treated so that manure does not accumulate and interfere with ventilation. Nest box litter must be renewed at very frequent intervals. Many diseases are spread by infected food and water, and these containers should receive special attention. Water bowls should be rinsed out daily before refilling and where wet mash is used, the troughs require regular cleaning or food rapidly moulds.

Birds should never be moved to new accommodation until the houses and utensils have been cleaned and disinfected. Similarly, when houses are vacated, or when disease has occurred, they should be treated in the following manner. After removal of the birds, the litter, floors, walls and ceilings should be sprayed with an approved disinfectant in the recommended strength. This lays the dust and disinfects the bedding. The walls and floor are then scraped down and the scrapings and bedding removed (if disease has been present the waste should be incinerated) to the manure heap. The interior of the houses and all equipment must then be scrubbed with hot water containing 4 per cent. washing soda to remove the grease and dirt. After it has dried, the house should be finally sprayed with a disinfectant and left exposed to the air and sunlight for as long as possible. A 10 per cent. watery solution of household ammonia is the best agent for the destruction of coccidia, while for external parasites, D.D.T. or Gammexane should be used.

Incubators require special treatment and the most satisfactory method is fumigation with formaldehyde gas. The gas is liberated by placing potassium permanganate in a bowl and pouring commercial 40 per cent. formalin on top. The recommended amounts are 4½ oz. formalin to 3 oz. potassium permanganate for every 100 cu. ft. of air space. Hatched chicks should not be exposed to these higher levels of the gas and eggs should not be fumigated during 24th to 48th hours of incubation. Full details regarding hatchery hygiene are given in the Regulations of the Poultry Stock Improvement Plant. Movable parts, such as trays, should be scrubbed with hot water and washing soda and washed or sprayed with a solution of sodium hypochlorite. Fluff and dust can be removed by vacuum cleaner and together with the egg shells and other incubator debris burned or incinerated.

Little can be done to decontaminate infected ground, except to rest the runs for the longest available period—12 months if possible. Grass should be kept short to permit of the maximum exposure to the air and sunlight. Liming at the rate of two tons to the acre is said to be beneficial.

Where fixed houses are used, the soil immediately around the house should be removed to a depth of one spit, the exposed sub-soil sprayed with disinfectant and covered with layers of clinker and fine ashes.

A sick bird is the greatest source of danger to the rest of the flock and must be immediately isolated or culled. Dead birds should be buried or burned.

Newly purchased, or returned stock, should be isolated for 21 days before being mixed with the flock.

Discourage visitors from entering poultry houses or pens and prevent all poultry from gaining access to swill until it has been boiled. Eliminate vermin, keep young stock separate from older birds and buy stock only from a reputable source where controlled blood testing is practised.

Finally, seek qualified, authoritative advice if disease appears and seek it promptly.

DAIRYING

CONSTITUENTS OF MILK

These are shown in the following diagram:—

- Milk
  - Water
  - Total Solids
    - Fat
    - Solids-not-Fat
      - Nitrogenous substances
        - Proteins
          - Casein
          - Albumin
          - Globulin
        - Non-proteins
      - Lactose
      - Mineral salts
        - Phosphates, citrates, chlorides of sodium, potassium, calcium, magnesium. Traces of copper, iron, manganese, iodine, etc.
      - Other substances including Vitamins A, B, C, D & E

Fig. 25

TABLE 56: AVERAGE COMPOSITION OF MILK

The following table is based on the reports of various workers in Great Britain who have examined large numbers of samples.

Author	Period	No. of Samples	Source	Average Percentage Composition		
				Water	Fat	Solids-not-Fat
Richmond	1900–1920	330,000	Southern England	87·48	3·78	8·74
Baker & Cranfield	1923–1931	300,000	Midlands	87·48	3·61	8·91
Elsdon	1903–1934	771,000	England	87·62	3·61	8·77
Golding *et al.*	1930–1932	3,115	Southern England	87·22	3·89	8·89
Crowther	1904	4,220	Yorkshire	87·52	3·70	8·78
Tocher	1923	676	Scotland	87·27	3·95	8·78
Provan	1945–1949	200,000	England & Wales	87·73	3·60	8·67

Thus considerable variation may occur in "average composition" of milk as reported by various workers. The larger the bulk of milk, the more constant is the composition, but even then there are wide variations which may occur due to breed, season of the year or district.

TABLE 57: VARIATIONS IN COMPOSITION OF MILK

The following variations have been reported by various authorities:

	Butter Fat Per cent.			Solids-not-Fat Per cent.		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Richmond ...	6·39	1·03	3·78	10·60	4·90	8·74
Crowther ...	5·30	2·00	3·70	9·50	8·40	8·78
Tocher ...	7·50	1·66	3·95	10·66	7·00	8·80
Golding *et al.*	5·17	2·60	3·88	9·28	8·40	8·91

TABLE 58: SEASONAL VARIATIONS IN THE COMPOSITION OF MILK

Month	1897–1916 Buckinghamshire (Droop Richmond)			1945–1949 England and Wales (Milk Marketing Board Creameries)		
	Total Solids Per cent.	Butter-Fat Per cent.	Solids-not-Fat Per cent.	Total Solids Per cent.	Butter-Fat Per cent.	Solids-not-Fat Per cent.
January	12·75	3·79	8·96	12·31	3·64	8·67
February	12·67	3·72	8·95	12·22	3·57	8·65
March	12·62	3·67	8·95	12·13	3·51	8·62
April	12·54	3·65	8·89	12·09	3·47	8·62
May	12·50	3·56	8·94	12·12	3·39	8·73
June	12·42	3·52	8·90	12·21	3·44	8·77
July	12·39	3·63	8·76	12·23	3·52	8·71
August	12·51	3·76	8·75	12·26	3·57	8·69
September	12·70	3·85	8·85	12·40	3·68	8·72
October	12·84	3·91	8·93	12·53	3·78	8·75
November	12·94	3·98	8·96	12·53	3·81	8·72
December	12·87	3·91	8·96	12·39	3·72	8·67

TABLE 59: COMPOSITION OF MILK (E. R. LING)

	Per cent.
Water...	87·54
Fat	3·71
Nitrogenous substances—	
Proteins—Casein	2·63
Albumin ...	0·31
Globulin ...	0·11
Non-Protein	0·24
Lactose	4·70
Ash	0·76
	100·00

TABLE 60

COMPOSITION OF MILK FROM VARIOUS MAMMALS

	Total Solids Per cent.	Fat Per cent.	Casein Per cent.	Other nitrogenous substances Per cent.	Lactose Per cent.	Ash Per cent.
Human ...	12·59	3·78	1·03	1·26	6·21	0·31
Cow	12·46	3·71	2·63	0·66	4·70	0·76
Ewe	19·18	6·86	4·97	1·55	4·91	0·87
Goat ...	14·29	4·78	3·20	1·09	4·46	0·76
Mare ...	9·30	1·20	1·90	0·10	5·70	0·40
Sow	15·96	4·55	7·23		3·13	1·05
Buffalo ...	18·59	7·47	5·85	0·25	4·15	0·87
Elephant ...	32·15	19·57	3·09		8·84	0·65

TABLE 61

COMPOSITION OF COLOSTRUM

	Total Solids Per cent.	Butter Fat Per cent.	Total Protein Per cent.	Lactose Per cent.	Ash Per cent.
First milking	24·55	3·89	16·76	2·50	1·33
Second milking ...	18·00	3·84	9·33	3·52	0·97
Third milking ...	16·79	3·11	7·06	3·85	0·96
Fourth milking ...	15·21	3·82	6·16	4·23	0·88

Average of Observations by 25 investigators. (E. R. Ling.)

TABLE 62: COMPOSITION OF BULKED HERD MILK FROM DIFFERENT BREEDS—
1945–1947

Breed	Average Composition as Received at Milk Marketing Board Creameries	
	Butter Fat Per cent.	Solids-not-Fat Per cent.
Channel Island	4·41	8·93
Ayrshire	3·72	8·73
Shorthorn	3·65	8·68
Friesian	3·45	8·58

TABLE 63: WEIGHTS OF SOLIDS IN ONE GALLON OF MILK

	12·5 per cent. Total Solids	14·0 per cent. Total Solids
	oz.	oz.
Butter Fat	5·74	7·79
Lactose	7·87	7·87
Albumin	0·66	0·66
Casein	5·08	5·41
Ash	1·15	1·23
	20·50	22·96

RELATIONSHIP BETWEEN CONSTITUENTS

Fat and Solids-not-Fat—There is an average relationship between these two fractions, but this may not apply to individual samples of bulked milk or milk from individual animals. As far as breeding is concerned, there is evidence that butter fat and solids-not-fat contents are separately inherited characteristics, but there is evidence that increasing the butter fat is accompanied by an increase of solids-not-fat.

Lactose, Protein and Ash—Vieth gives the ratio between these constituents for normal milk as 13 : 9 : 2. This ratio can be used as a test of adulteration, as addition of water will not affect the ratio while, with genuine milks of poor

chemical composition, the ratio does not hold. There may be wide variations from the ratio with individual samples.

Chlorides and Lactose—There is an inverse relationship between these constituents, a high chloride being associated with a low concentration of lactose and vice versa.

MILK CONSTITUENTS

Water—Water in milk exists as ordinary water, but cannot be separated from the milk solids except by a chemical means or by evaporation. It forms from 84 to 90 per cent. of the milk by weight, but extreme figures are only obtained with small bulks of milk such as those from individual cows.

Butter Fat—Butter fat exists as an emulsion of tiny drops or globules suspended in the milk serum, the serum consisting of a solution of lactose, protein and mineral substances. It is now acknowledged that there is no protein membrane surrounding each globule, but that the molecular force of the small globules is sufficient to give a thin watery covering of milk serum constituents, giving the physical properties of a membrane. One pound of milk with a butter-fat content of 4 per cent. contains about 40,000 million fat globules. The largest fat globules in cream are 0·0005 to 0·0006 in. in diameter, and the smallest may be one-tenth of this. The size varies in different breeds, the largest butter-fat globules being present in Jersey milk and the smallest in Ayrshire and Friesian milk, the size of the fat globule diminishing from the time of calving. Large globules are most easily churned; thus cream with:

Size of Globule	May be churned in
0·000225 in.	13 minutes
0·00019 in.	30 ,,
0·00018 in.	34 ,,

Large globules are best for butter-making—such as in Jersey milk—and small ones for cheese. The larger ones rise more rapidly into the cream and churn more readily, while the smaller ones may never rise, and tend to make an even textured cheese.

Proteins—Casein is the principal one and it is in colloidal solution in the form of a dilute jelly swelled up by absorption

of water. It will not dialyse, but when curdled dissolves in dilute hydrochloric acid or sodium hydroxide.

Of the other proteins present, the principal one is albumin. Casein is coagulated by the addition of acids or rennet, but not by boiling. Albumin is not coagulated by rennet or most acids but by heat. Colostrum contains a high proportion of albumin, and therefore coagulates on boiling.

Lactose (**Milk Sugar**)—Lactose is the principal carbohydrate present in milk and is in true solution. It can be crystallised from whey by evaporation.

Ash—Ash consists of various salts partly in solution, of which calcium and potassium phosphates and sodium chloride predominate. Some calcium is loosely bound with the casein as calcium caseinate. The other minerals such as copper, manganese, magnesium, cobalt, are mostly in solution, but the quantities present are very small. The proportion of ash remains fairly constant in normal milks and, therefore, a decided reduction in this constituent may be an indication of added water.

Colouring Matters—Milk contains the yellow colouring matter carotene. It is present in greatest proportions during the summer and in milk from the Channel Island breeds and is responsible for the deeper yellow colour of the fat. The concentration is also higher in the colostrum of all breeds. This colouring matter is the same as that of plants and can be increased by feeding foods rich in carotene such as carrots or young spring grass. A water-soluble pigment—riboflavin—is responsible for the greenish colour in whey.

FACTORS INFLUENCING SECRETION AND CHEMICAL COMPOSITION OF MILK

Breed—The breeds of dairy cattle recognised in this country are Shorthorn and Lincoln Red Shorthorn, Friesian, Devon and South Devon, Red Poll, Ayrshire, Jersey, Guernsey, Kerry, Dexter, Welsh Black and British White. The comparative yields of each have been given in Table 37. The Channel Island breeds—Jersey and Guernsey—produce milk containing the highest proportion of fat and solids-not-fat, while the Friesian produces, on average, the poorest milk.

Temperament — An animal with a healthy, well-developed nervous system milks better than one with a sluggish, phlegmatic temperament, i.e., the most intelligent cow is the best milker. Such animals require very careful treatment or they degenerate into nervous, fidgety, easily frightened animals with reduced milk yields and tend to produce milk with widely fluctuating variations in composition, particularly in butter fat.

Health—Cows must be healthy to give high yields of good quality milk. The most serious troubles are tuberculosis and various ailments of the udder, such as mastitis, wounds, etc. Sheds must be sanitary, well lighted and well ventilated. Udder troubles can cause deterioration in the milk secreted, e.g., mastitis in the early stages may reduce the yield with an accompanying increase in butter fat and decrease in the solids-not-fat content. Serious infection may result in a milk which is deficient in fat and solids-not-fat.

Age—A cow in good health continues to improve in milking capacity up to her 7th or 8th lactation, and the yield remains high until the 10th or 12th lactation. The milk of heifers is richer in fat and solids-not-fat than in succeeding lactations. The decrease in butter fat from one lactation to the next is of the order of 0·03 to 0·04 per cent. of butter fat, while the decrease in solids-not-fat is about 0·1 per cent. for the first four lactations and becomes less in later lactations.

Period of Lactation—The cow attains her highest yield about six to eight weeks after calving. The yield then declines and the cow naturally dries off about nine months after calving. The fat and solids-not-fat contents of milk decrease as the yield increases, so that fat and solids-not-fat contents are at their lowest during the period of maximum milk production. The only constituent of milk which is high in the period of maximum production is the lactose.

Period of the Year—The flush of young grass in early summer stimulates the milk yield of cows in whatever period of lactation they may be, while the dry, brown pastures and hot weather of summer depress the yield. There is a marked seasonal variation in both fat and solids-not-fat as shown on p. 509. The butter fat is softer in summer than in winter, irrespective of temperature. This is due to an increase in

olein content of the butter fat in the summer and of stearin in the winter.

Oestrus—The service heat has little effect on some cows, but in most cases the quantity of milk is reduced. This may be accompanied by quite large variations in the butter fat content of the milk which may be increased or decreased by one per cent. or more. There is little effect on the solids-not-fat content. These changes are temporary, lasting only two or three days, and disappear immediately the oestrus is over.

Food—Food largely influences the quantity of milk, but it can also influence the composition of the milk. Poor feeding results in low yields, a small decrease in butter fat and, in many instances, a marked decrease in the solids-not-fat. The seasonal variation in solids-not-fat is partly due to poor nutrition during the winter months which results in a very low level of solids-not-fat in late winter. Similarly, the increase in solids-not-fat on turning out to spring pasture is probably due to the higher nutritive value of young spring grass as compared with winter rations, while summer grass of lower nutritive value in accompanied by a decrease in solids-not-fat. The presence of oestrogens—or milk stimulating substances—in early spring grass may be responsible for the increase in yield and improved composition of spring milk.

Proper feeding is important in maintaining both the yield and composition of milk and treatment prior to calving—steaming up—is essential. If a cow calves down in good condition, she has reserves of fat and flesh which can be utilised to provide for the period of maximum yield.

Feeding stuffs such as young oats or lush spring grass which are low in fibre and high in protein can cause a reduction in the butter fat content. The same effect will be obtained during winter feeding if a high energy production ration is fed without sufficient hay or other fibrous food.

Soil—Although it is generally held that the nature of the soil influences the quality of the milk, presumably through pasture and other crops, there is no evidence to show that this is true. There are indications, however, that some fields are responsible for a lower fat content than others, and also that milk from limestone soils is less heat stable than that from other areas.

Water Supply—A plentiful supply of good water is essential in both summer and winter. According to the Geneva (N.Y.) experiments with seven different breeds, cows require about five gallons of water to every gallon of milk yielded, every 1 lb. of dry food requiring 3 to 4 lb. of water.

Temperature—Cows yield best when kept at a temperature of 40–50° F. This is often exceeded in summer, but in winter it is always possible to keep the air temperature of the cow houses up to this from the natural heat of the animals alone and, at the same time, have proper ventilation. Cows are more liable to take chills if, during winter, they are turned out for exercise from warm, badly ventilated sheds. Yields are reduced slightly by low temperatures and this is accompanied by an increase in butter fat.

Exercise—A certain amount of exercise is beneficial. It has been stated that, as compared with cows at rest, the fat in milk may be 0·3–0·4 per cent. richer in cases of those animals getting exercise, while the total milk yield is maintained or even improved.

Weather—A frost causes an immediate reduction in yield which may be only temporary. A hot, dry period in summer has the same effect. Continuous dry, hot weather reduces the solids-not-fat, but increases the fat content. This is probably bound up with the nutrition of the animal.

Treatment of the Animal—Gentle treatment is of utmost importance, as anything upsetting to the animal causes " hold up " of milk and eventually decreases the daily yield. Cows should never be worried and always handled quietly. When pestered by flies, the yield is adversely affected. Quick and clean milking increases both quantity and quality of milk, while slow, slovenly work adversely affects both and causes premature " drying off." Inefficient milking may injure an animal to an extent that cannot be remedied. Babcock found that quick milking compared with slow milking produced from 2 to 13 per cent. more milk which was richer in fat, and this continued for several months until the normal lactational decline occurred. This has been confirmed by other workers. Much of the variation of fat content is due to inefficient milkers.

Milking machines are increasing in popularity and, properly managed, are as efficient as hand milking and, in

addition, are labour-saving, particularly in the larger herds. They may be economical for herds of ten cows or less. Milking machines should be handled by skilled personnel, as much of the trouble experienced with mastitis and other udder complaints on installation of a milking machine is caused by poor management. They must not be left on too long or allowed to " creep," as this injures the udder tissues. Machines must be properly cleaned and sterilised to prevent spread of mastitis and other udder troubles and produce milk of good hygienic quality. There is considerable difference of opinion as to whether hand stripping is necessary after the machine. General experience seems to indicate that it is unnecessary if the udder is massaged before removing the machine.

Milking Intervals—There is a tendency for more milk containing less fat to be given at the morning milking. The difference is least when the periods between milking are exactly 12 hours and is accentuated when the night period becomes longer than the day period.

There is little variation in the solids-not-fat content of milk, but there is a tendency for morning milk to be richer than evening. Where three times a day milking is practised, milk during the day is usually richer in fat than that obtained during the night periods, even when the milking periods are equal.

Stripping—The fat content of milk varies during milking, as shown in the following table:—

TABLE 64: FAT CONTENT OF MILK DURING MILKING

Portion	Cow " A "	Cow " B "	Cow " C "
First ...	0·90	1·60	1·60
Second ...	2·60	3·20	3·25
Third ...	5·35	4·10	5·00
Strippings ...	9·80	8·10	8·30

The solids-not-fat content tends to fall as the fat increases.

From this it will be seen complete milking is necessary not only to obtain maximum yields, but also maximum butter-fat content.

Souring of Milk—Milk is an ideal medium for the growth of many organisms. These cause various chemical changes

in the milk and are responsible for souring. The bacteria normally found in milk may be divided into two main groups:—

(*a*) Those producing lactic acid from lactose
and (*b*) Those which attack the protein and often produce bacterial rennet.

The main sources of these organisms are the surfaces of equipment, the cow, the milker and the air. Milk as it leaves the healthy cow contains very few organisms, but contamination may take place immediately after milking. Bacteria gain entry with dirt from the cow or any of the sources given above. The most serious source of contamination is, however, the surfaces of inefficiently cleaned utensils.

Normally, souring is brought about by the lactic acid producing bacteria. These convert the lactose into lactic acid which accumulates in the milk until, finally, sufficient is present to precipitate the casein and clot the milk. Souring occurs most rapidly at temperatures of 60–90° F., lactic acid producing bacteria growing best in this range. Milk with a titratable acidity of 0·20–0·25 per cent. lactic acid tastes sour, with an acidity of 0·3 per cent. clots on boiling, and with an acidity of 0·6 per cent. curdles spontaneously.

The organisms mainly responsible for lactic acid production are the lactic acid producing streptococci, e.g., *Streptococcus lactis* and the coliform organisms, the latter producing large quantities of carbon dioxide and hydrogen in addition to lactic acid. Sweet curdling may occur occasionally, and this is sometimes due to aerobic proteolytic spore-forming organisms.

To ensure that milk has a long life before souring, every precaution must be taken during the production to prevent contamination. This can only be done by paying attention to hygiene during production and handling. Milk should always be produced from clean, healthy cows, handled in clean, sterile utensils, and be cooled and kept cool until delivered to the consumer.

A very high proportion of the milk delivered to consumers is now heat-treated. The officially recognised methods of heat-treatment are:—

(*a*) *Pasteurisation* (1) The holder method in which the milk is held at 145–150° F. for at least 30 minutes before

cooling immediately to 50° F. or lower, and (2) The High Temperature Short Time method where milk is held at a temperature of at least 161° F. for at least 15 seconds before cooling immediately to 50° F. or lower.

(*b*) *Sterilised Milk*—Where milk is held at 212° F. or up to 225° F. in autoclaves for at least half an hour. This milk is heated in the bottle and cannot be cooled quickly.

Both these methods destroy milk souring organisms, but they are not a cure for poor methods of production. It has been shown, especially under summer temperatures, that raw milk with a high bacterial content has a less satisfactory keeping quality after pasteurisation than that of milk properly produced. There is also the question of flavour, and milk of a poor hygienic quality has a poor flavour after heat treatment.

Cleansing of Milk Equipment—(*a*) Immediately after milking, all equipment coming into contact with the milk must be rinsed in cold water. This removes most of the milk solids.

(*b*) Utensils should be thoroughly scrubbed in warm detergent solution to remove traces of fat and other milk solids which are not removed by the cold water rinse.

(*c*) Utensils should be sterilised to destroy any bacteria not removed by cleansing. The best form of sterilisation is in a steam chest at 210° F. for 10 minutes or by complete immersion in boiling water for 2–3 minutes, but chemical sterilising agents, e.g., sodium hypochlorite, are satisfactory if properly used.

Detergents—Detergents are cleansing agents and must not be confused with sterilising agents such as sodium hypochlorite. Commonly used detergents are washing soda or soda ash (sodium carbonate), trisodium phosphate, the sodium silicates and sodium hydroxide. The latter cannot be used for hand washing of dairy equipment owing to its effect on the hands. There is no necessity for an expensive detergent in normal farm practice and for stainless steel or tinned utensils, washing soda or preferably soda ash are satisfactory. Where aluminium equipment is used, it can be

easily corroded by soda ash and it is advisable to use a detergent with a high proportion of sodium metasilicate.

The detergents have the property of emulsifying the fat on the surface of the equipment and promote easy removal. They are not efficient unless properly applied by scrubbing.

Sodium Hypochlorite—This is a sterilising agent with very little cleansing action, the use of which has only been allowed officially in Great Britain since 1941. It is not efficient when used with poorly cleaned utensils, attacking milk residues in preference to bacteria.

Brands of sodium hypochlorite must be approved by the Ministry of Agriculture, Fisheries and Food and contain a small quantity of sodium chlorate to act as an indicator which can be detected if the hypochlorite is added to milk. The approved hypochlorites are sold under trade names such as Chloros, Deosan, Delsanex, Dairozone and Hyposan. The best method of application is as follows:—

(*a*) Rinse equipment thoroughly in cold water.
(*b*) Scrub thoroughly in chlorine-wash solution containing ¼ lb. soda ash or other dairy detergent or ½ lb. washing soda and 4 oz. of the sodium hypochlorite solution as purchased per 10 gallons of water at 110–120° F.
(*c*) Rinse in water to which sodium hypochlorite has been added at the rate of 1 oz. per 10 gallons.

Quaternary Ammonium Compounds—These can be approved by the Ministry of Agriculture, Fisheries and Food for use in the sterilisation of equipment.

HYGIENIC MILK PRODUCTION

The essential points are:—

1. Healthy and clean cows.
2. Keen personnel.
3. Healthy milkers with clean hands and clothing.
4. Clean, sterile milking equipment.
5. A good water supply.
6. Clean cowsheds.
7. Good cooling and storage.
8. A good milking routine including discarding the foremilk.

MILK EQUALISER

On account of the variations in the milk from different cows during the course of the milking, there is often a difference in butter-fat content of the milk in churns making up any consignment. To obviate this, the equaliser which is fitted below the cooler is used to distribute the milk equally over several churns at once so that the butter-fat contents of all are the same.

This cannot be adapted for bottled milk, and here it is essential that milk from as many cows as possible should be bulked together before bottle filling commences.

Cooling

Milk should be cooled to below 60° F. before sale. This can be done with a surface cooler, but the efficiency of cooling depends on the water supply used. A good deep well provides water at 52–53° F., which enables milk to be cooled to 54–55° F. at all periods of the year. Where mains water is used, its temperature fluctuates and, during hot summer weather, it may be impossible to cool below 75° F. Mechanical coolers may be necessary under such circumstances and may be of the direct expansion, chilled water or immersion types. With surface coolers, it is possible to cool to within 2° F. of the water temperature by passing water through the cooler at three times the rate of milk flow. This requires considerable care in adjusting the rate of flow.

MILK TESTING

Butter Fat Determination—The only accurate method of determination of butter fat is by extracting the fat with a suitable solvent and weighing it. However, the Gerber method—which depends on dissolving the proteins with sulphuric acid and separating the fat by centrifuging in a calibrated butyrometer—gives very reliable results when properly carried out; 10·94 ml. of milk is mixed with 10 ml. of sulphuric acid (s.g. 1·82–1·825) and 1 ml. of amyl alcohol (s.g. 0·810–0·812). All equipment should be checked for accuracy, speed of centrifuge should be 1,100 r.p.m., and spinning should be continued for at least four minutes.

Determination of Total Solids—The most accurate method is by drying at 100° C. A routine method which

gives satisfactory results depends on determination of the butter-fat content by the Gerber method, and the density by an hydrometer. The total solids can be calculated from the following formula:—

$$T = 0{\cdot}25\ D + 1{\cdot}22\ F + 0{\cdot}72$$

where T = Total Solids,
D = (Density at 20° C. − 1) × 1000
and F = Fat

This formula applies to milk with fat in the liquid state. For milk with fat in the solid state the following formula should be used:—

$$T = 0{\cdot}25\ D + 1{\cdot}22\ F + 0{\cdot}55$$

These formulae are taken from British Standard No. 734, 1955 Amendment No. 1, 1st October, 1957.

This routine method has been shown to give reliable results for bulk milk and for samples from individual cows with normal butter-fat contents of 2·0–6·0 per cent., but there may, in some instances, be quite wide variations from the figures obtained by drying. It is essential that the test is carried out under standard conditions and for this reason the British Standard method should always be used.

Dye Reduction Tests—These have, to a large extent, replaced bacteriological methods depending on determination of numbers of bacteria or specific organisms such as the coliform group which produce both acids and gas from lactose. It is essential that samples should be aged before testing, as all milks will give a satisfactory result which gives no indication of the hygienic quality if the tests are carried out immediately after milking. They are carried out by adding 1 ml. of a dye such as methylene blue or resazurin to 10 ml. of milk and incubating at 37° C. The products of bacterial activity bleach the dyes and the test is complete for methylene blue when the dye is completely decolourised.

Milks produced under the Milk (Special Designations) Regulations, 1949, should not decolourise methylene blue in 5½ hours in winter (November to April), or 4½ hours in summer (May to October).

The resazurin test is used as a measure of marketability. The dye resazurin is reduced by bacterial activity from purple through pink to colourless. The test is carried out by adding 1 ml. of standard resazurin solution to 10 ml. of milk,

and then incubating at 37° C. for 10 minutes. Any consignments which completely decolorise the dye are rejected as having poor hygienic quality and, for certain purposes, milk which reduces resazurin to the violet or pink stage may be returned to the producer.

Freezing Point Test (Hortvet)—At certain periods of the year, milks may be genuine and yet fall below the presumptive legal standards for either fat or solids-not-fat. The freezing point of milk indicates whether milks are genuine or whether they have been adulterated with water. Milk freezes at a lower temperature than water and the addition of water brings its freezing point nearer to that of water, i.e., the difference between the freezing point of water and that of milk—the freezing point depression of milk—is reduced by the adulteration.

The freezing point is determined with special apparatus, and it has been shown that the average freezing point depression of milk is 0·545° C. and for individual samples rarely falls below 0·530° C. If a milk has a freezing point depression of 0·529° C. or less, it can be taken as evidence that the milk has been adulterated. The test is not a statutory one, but it is used generally to provide confirmation of the results of butter-fat and solids-not-fat determinations.

Titratable Acidity—The so-called acidity of fresh milk when titrated with alkali using phenolphthalein as an indicator is due to the protein, soluble phosphates and carbon dioxide. The figure obtained will therefore, to some extent, depend on the solids-not-fat content of the milk. The development of lactic acid during souring increases the value obtained.

The titratable acidity is usually determined by taking 10 ml. of milk or whey, adding 1 ml. of a solution containing 0·5 per cent. phenolphthalein in 50 per cent. alcohol and titrating with N/9 sodium hydroxide solution (containing 4·444 gr. per litre) until a faint pink colour is obtained. The result is reported as percentage of lactic acid, given by the number of millilitres of sodium hydroxide used divided by 10, as 1 ml. of N/9 alkali is equivalent to 0·01 gr. of lactic acid.

The initial acidity of milk is usually between 0·140 and 0·160 per cent. lactic acid. A lower figure is obtained with

milk from cows infected with mastitis or at the end of the lactation, and a high figure for cows immediately after calving.

Specific Gravity and Density of Milk

Normally, the specific gravity of milk is determined at 60° F. (15·5° C.) and the density at 20° C.

The normal range is:—

Specific gravity	(60° F.)	1·026 to 1·036
Density	(20° C.)	1·025 to 1·035

The specific gravity and density of milk are reduced by addition of water.

When cold milk is allowed to stand at air temperature, the specific gravity and density increase until, at about 12–42 hours after milking, they reach a maximum. This phenomenon is known as the Recknagel contraction and is probably due to solidification of the butter-fat globules, hydration of the protein and loss of carbon dioxide. The effect of this factor should always be guarded against in determinations of specific gravity or density and, to obtain standard conditions, the milk should always be warmed to 40° C. and then cooled to the temperature at which the determination is carried out.

Skimmed milk has a higher specific gravity than the original milk because of the removal of the less dense fat.

Methods of Calculating Extent of Adulteration of Milk

If the butter-fat content of milk falls below 3 per cent. or the solids-not-fat content below 8·50 per cent., it may be presumed, until the contrary is proved (Food and Drugs Act, 1938), that the milk has had fat abstracted or that water has been added. The minimum per cent. of fat abstracted or water added may be calculated as follows:—

$$\text{Minimum per cent. of fat abstracted} = \frac{(3 - \text{Fat per cent. in milk}) \times 100}{3}$$

$$\text{Minimum per cent. of added water} = \frac{(8{\cdot}5 - \text{S.N.F. per cent. in milk}) \times 100}{8{\cdot}5}$$

Where the freezing point (Hortvet) determination can be carried out, and an appeal-to-the-cow sample is available in

the case of a suspect milk the added water present may be calculated by means of the formula

$$\frac{T - T_1}{T} \times (100 - \text{t.s.})$$

where T = Freezing point depression of genuine (i.e., unwatered, appeal) sample.

T_1 = Freezing point depression of suspect (adulterated) sample.

t.s. = Total solids.

Should appeal-to-the-cow samples be not available T may be taken as 0·530° C. except for samples of over 200 gallons when the value for T should be taken as 0·540° C. In such cases, it has been suggested, the following simple formula may be used:—

$$\frac{T - T_1}{T} \times 100$$

This calculation is applicable to nearly all samples since the freezing point of genuine milk varies within the narrow range −0·530° C. to −0·550° C., very few cases occurring of cows which produce milk that falls outside these limits.

Taints in Milk

These may be due to a number of causes:—

(*a*) Absorbed odours,
(*b*) Chemical taints,
and (*c*) Bacterial taints.

Milk readily absorbs odours giving "cowy," paraffin, disinfectant or silage taints. It is therefore important that milk should always be handled in clean, sweet-smelling premises.

Chemical taints may be due to advancing lactation or disease of the udder, illness of the cow as in acetonaemia, food consumed by the cow or changes in the fat brought about by the action of oxygen in the presence of light or traces of copper. Lactational changes or mastitis may give a salty flavour, and acetonaemia a taint due to the presence of acetone.

Food taints are very common and may be due to:—

(*a*) Feeding excessive quantities of turnips or other roots or rape kale, especially in a slightly decomposed condition.

(*b*) Feeding sugar beet products, and particularly molassed sugar beet pulp, which produces a fishy flavour.
(*c*) The presence of weeds such as garlic, mustard and even clover.

Food taints can usually be eliminated by feeding foods such as turnips and sugar beet products immediately after milking. Weed taints can only be overcome by removing them from the pastures or, in the case of clover, by controlled grazing.

Bacterial taints are caused by the growth of organisms which produce aroma and flavour-producing substances from the milk constituents. These flavours may be " malty," fruity or even turnipy, and they are always absent from the milk immediately after milking, but develop on standing. This differentiates them from the absorbed and chemical taints, with the exception of the " oily " or " cardboard " taints caused by the action of sunlight, or the presence of small quantities of copper derived from badly tinned copper equipment.

Bacterial taints can be controlled by thorough cleanliness and sterilisation of all equipment. Occasionally, infected water supplies may be responsible and, in this case, a small quantity of sodium hypochlorite can be used in the water used for washing the cows.

" Ropy milk," due to bacteria which cause the milk to draw into long threads, is another trouble which, although not a taint, may be controlled in the same way as a bacterial taint.

MILK RECORDING

It is beneficial to weigh the milk night and morning at regular intervals—daily, weekly or monthly—to determine the milk producing capabilities of the animals in the herd. This is essential for culling, breeding and feeding. Weighing is more accurate than measuring, and weights in lb. can be converted easily to gallons by dividing by 10·32—the average specific gravity of milk.

Recording the weight of milk need not be carried out under any official scheme, but it is usually found to be an advantage, especially where cows and bulls are sold off the farm and where officially recorded animals command a better market. In addition, the official schemes—in all countries—provide a

butter-fat testing service which enables breeding to be based on quality in addition to quantity of milk. This is important, as the butter-fat content tends to decrease with increasing yields, and it is only by attention to both that the quality of the milk can be maintained.

In England and Wales, official milk recording is administered by the Milk Marketing Board through National Milk Records and its branch committees, the scheme being introduced in 1942 when it replaced the scheme administered by the Ministry of Agriculture. In Scotland, the scheme is administered by Scottish Milk Records and in England, Wales and Scotland, financial assistance is given by the Government.

A milk record should give at least the following particulars: (1) Sire, (2) Dam, (3) Ear mark or number of cow and name of cow, (4) Breed, (5) Age and number of calves produced, (6) Date of birth of last calf, (7) Date next due to calve, (8) Number of days in milk, (9) Weight of milk produced during lactation, (10) Percentage of fat calculated on a lactation basis and number of samples examined.

CREAM

Cream may be obtained from milk either by hand skimming or by mechanical separation. For hand skimming, the milk is " set " in shallow pans to allow the cream to rise, and this is then skimmed off with a scoop 12–24 hours later. During setting it is advisable to keep the milk as cool as possible to prevent souring and development of taints. Hand skimming is inefficient, leaving a high proportion of fat in the skimmed milk—0·25–0·5 per cent., does not allow the proportion of fat in the cream to be controlled, and may also give a cream of poor keeping quality because of the growth of the milk bacteria during setting. This method of obtaining cream has been almost entirely superseded by the mechanical method of separation except in the manufacture of Devonshire and Cornish clotted cream. In this case, the milk is set in shallow pans at 60° F. for 12 hours. The temperature of the milk is then raised to 180–190° F. and held at this temperature until the surface becomes wrinkled. The cream takes on a " broken " appearance on cooling. It is then skimmed by hand. Losses of butter-fat are less by this method, and the cream has a better keeping quality.

In mechanical separation, the milk passes in a continuous flow through plates revolving at 5,000 revolutions per minute or more. By this means, the rising of the fat globules is assisted by centrifugal force, as the heavier skimmed milk is thrown towards the outside of the plates and the lighter fat globules accumulate nearer the centre. The cream obtained can be drawn off from the centre of the plates and the skimmed milk from the outside. Mechanical separation is most efficient when the temperature of the milk is at least 95° F. Mechanical separation has the advantages that a high proportion of the butter fat is removed, leaving not more than 0·1 per cent. of fat in the skimmed milk, and that a " fresh " cream is obtained. In addition, the percentage of fat in the cream can be regulated by adjustment of the cream screw.

The proportion of butter fat in the cream should be varied according to the purpose for which it is required. A thin cream containing about 20 per cent. of butter fat is suitable for coffee and fruit, one containing 30–40 per cent. fat for buttermaking, and over 40 per cent. for whipping. If the percentage of fat in the milk is known, the approximate percentage of fat in cream is given by the formula:—

$$\frac{(\text{percentage fat in milk} - 0{\cdot}1) \times \text{volume of milk used}}{\text{volume of cream obtained}}$$

The percentage of fat in cream is most accurately determined by extraction of the fat with a suitable solvent, and weighing the fat obtained, but a comparable figure can be obtained by the Gerber method, using 5 gm. of cream in a special butyrometer.

The specific gravity of cream varies with the fat content from 1·027 to 0·95, but may be taken as an average of 0·985 equal to 9·85 lb. per gallon.

Starters

A starter is a culture of lactic acid bacteria used to inoculate milk or cream to increase the rate of " ripening " in cheese and buttermaking. When milk or cream are ripened naturally, i.e., by the organisms already present, the resulting product may be poor because of fermentations which produce taints and other abnormalities. A vigorous and pure starter

prevents these and results in a better and more uniform product.

The role of starters in cheesemaking is to produce the lactic acid required in the cheesemaking process and to overcome the growth of other organisms which may lead to "off flavours." In butter-making, the starter is used to prevent the growth of organisms which may cause rancidity, to improve the churning properties of the cream, and the flavour and aroma of the butter.

Starters consist of lactic acid producing streptococci, e.g., *Streptococcus lactis* and *S. cremoris*, and occasionally lactic acid producing rod-shaped bacteria—*lactobacilli*. The ability of butter starters to produce the substance diacetyl—responsible for flavour and aroma—varies considerably with the strain of lactic acid bacterium. Some cultures have aroma producing bacteria present, e.g., *S. citrovorous*, although these produce very little lactic acid.

Propagation—Starter cultures may be obtained in liquid form from the dairy colleges or commercial firms. The life of a liquid culture is short, and the starter should be propagated as soon as received. "Powder" cultures can also be obtained which have the advantage of a fairly long life, but require repeated sub-culture before they are ready for use in either butter or cheese making.

Propagation should be carried out daily as follows:—

(*a*) Select a clean bulk of milk and pasteurise by heating to 180–190° F. for at least 60 minutes.
(*b*) Cool to 72° F.
(*c*) Inoculate with 1 per cent. (approximately 1½ oz. to each gallon of milk) of the starter culture.
(*d*) Store in a warm, clean room at a temperature of approximately 70° F.
(*e*) Repeat this procedure each day.

It is necessary to take every care in propagation of a starter as contamination with bacteria, yeasts, moulds or bacteriophage may seriously affect the butter or cheese made with it. It is therefore essential to sterilise **all** equipment used in the propagation of the starter and take every precaution to prevent contamination from the air. A starter is best propagated in a seamless container with a close fitting lid.

When propagation is properly carried out, the titratable

acidity 20–24 hours after inoculation should be 0·8–0·9 per cent. lactic acid. The curd should be smooth with no evidence of gas, and the starter should have a clean acid smell.

Rennet

Rennet solution as used in cheesemaking is a brine extract of the enzyme rennin which is present in the fourth stomach of the very young calf. The "vells" are collected from slaughter houses in all parts of the world, dried and despatched to the rennet factories where they may be stored until required. Rennet prepared from them contains the enzyme pepsin in addition to rennin. It is also possible to obtain rennet in tablet or powder form.

Rennet slowly loses strength in storage, and the loss is accelerated by the action of sunlight or high temperatures. Rennet tablets or powder retain their activity longer than liquid preparations.

The rennet acts on the calcium caseinate of the milk, with the precipitation of calcium paracaseinate.

Annatto

The colouring matter present in annatto is obtained from the seeds of the shrub Bixa orellana which contains a reddish yellow pigment—bixin. Cheese annatto is an alkaline aqueous extract of the seeds, while butter annatto is a solution of bixin in oil.

CHEESE

Cheesemaking probably originated as a method of preserving food in periods of plenty for periods of scarcity. Each district or country used its own methods for preserving the curd which was separated from the milk and from these, developed the various varieties of cheese with their own characteristic flavours. The basis of all cheesemaking processes is the precipitation of the curd—which consists mainly of casein, fat and some of the mineral salts—by the action of acid or rennet. This leaves the whey which contains nearly all the lactose of the original milk and some of the fat, proteins and ash.

The type of cheese obtained is dependent on the method of manufacture. The chief factor involved is the moisture

content which is controlled by the acidity developed at various stages of manufacture, the quantity of rennet used, the temperature attained at various stages, and the extent to which the curd is " pressed " to expel moisture.

The various types of cheese manufactured in Great Britain may be classified as follows:—

(*a*) *Hard pressed cheese*—Caerphilly, Cheddar, Cheshire, Derby, Double Gloucester, Dunlop, Lancashire, Leicester.

The method of manufacture is such as to provide conditions which favour ripening by bacteria and rennet.

(*b*) *Blue veined cheese*—Stilton and Wensleydale.

These are mainly ripened by the blue mould—*Penicillium roqueforte*—and the methods used are such as to give a cheese which favours the growth of this organism.

(*c*) *Soft cheeses*—There are no typical British soft cheeses, but French cheeses such as Camembert, Coulommier and Pont L'Eveque can be made under English conditions.

1. The milk used should be of good chemical and hygienic quality. The former is necessary to obtain a good yield of cheese from each gallon of milk, while milk of poor bacteriological quality may result in " off flavoured " cheese as well as causing other troubles.

2. **Ripening the Milk**—Acidity must be developed in the manufacture of hard-pressed cheese before rennetting, and does much to determine the course of acidity development during the succeeding processes. Starter is added to promote development of acidity, the milk being maintained at 85–90° F., the temperature at which starter organisms grow best. The quantity will vary with different cultures, but generally it may be said that the quantity which produces sufficient acidity for rennetting in 1–1½ hours is best.

3. **Rennetting**—Rennet is added to coagulate the curd, and the quantity, temperature and acidity of milk required vary with the variety of cheese. The rennet should be diluted with 3 or 4 times its volume of water before stirring into the milk.

4. **Cutting the Curd**—Cutting the curd into small particles assists removal of whey, the size of particle being smallest when a cheese of lowest moisture content is being made.

5. **Scalding**—Draining of the curd is assisted by raising the temperature of the whey above 90° F.—scalding. During scalding, the temperature of the whey is raised by about 1° F. every 3–4 minutes with continual stirring. If it is carried out more quickly, the surfaces of the curd particles are closed and too much whey is retained.

6. **Pitching**—The curd is allowed to fall to the bottom of the cheese vat. It may be allowed to remain in the whey for varying times or until a definite acidity has been attained by the whey.

7. **Drawing off Whey**—After pitching the curd lies as a mat on the bottom of the vat. The whey is run off and draining of the curd assisted by cutting and piling.

8. **Milling**—After the curd has attained the correct acidity and dryness, it is milled or ground and salted.

TABLE 65: TYPICAL PROCESSES FOR HARD-PRESSED CHEESE

	Cheddar	Cheshire
Temperature of milk ...	86° F.	86° F.
Quantity of starter	½–1½ per cent.	½–1 per cent.
Acidity at rennetting... ...	0·18–0·22 per cent.	0·22–0·23 per cent.
Temperature at rennetting ...	85–86° F.	86° F.
Quantity of rennet	1 oz. to 30 gal. of milk	1 oz. to 16–20 gal. of milk
Size of curd	small pea	small bean
Acidity after cutting	0·14–0·15 per cent.	0·14 per cent.
Temperature of scald ...	96–105° F.	89–93° F.
Acidity at pitching	0·175–0·19 per cent.	0·16 per cent.
Acidity when whey drawn off	0·24–0·28 per cent.	0·19–0·20 per cent.
Acidity at milling	0·65–0·95 per cent.	0·75–0·85 per cent.
Amount of salt	1 oz. to 3 lb. curd	1 oz. to 3 lb. curd

Pressing—After milling and salting, the curd is filled into moulds which, with Cheddar cheese, are immediately put into a press and bandaged after two or three days. For Cheshire cheese, the curd is held in the moulds in a room at 65–70° F. until the following day, when it is pressed for one or two days before bandaging.

Storage—After bandaging, Cheddar and Cheshire cheese should be stored at 55–60° F. to ripen, and each cheese turned daily for at least one month. During storage, various chemical changes take place under the action of the rennet, pepsin and bacteria. The casein is broken down into soluble substances which are responsible for the flavour of the cheese.

BLUE VEINED CHEESE

In the manufacture of this cheese, the milk is rennetted sweet, there is no scalding, and the whey is slowly expressed in cloth bags. The curd, after drainage, is broken up into coarse lumps which are filled into moulds, salt being added at the rate of 1 oz. to 2½ lb. of curd. The curd is not pressed and the necessary water and air conditions inside the cheese allow of growth of the penicillium mould which usually is present in the milk or which gains entry to the curd during manufacture.

Defects of Cheese

Slowness of Starters—(*a*) *Inhibitory Milk*—Certain organisms which develop on the surfaces of badly cleaned and sterilised utensils grow in milk and produce substances which slow the growth of the starter bacteria. All milk for cheesemaking must be produced in clean, sterilised utensils.

(*b*) *Bacteriophage* (*phage*)—It has been demonstrated that an ultra-microscopic infection of starters—phage—causes destruction of the starter organisms. This infection grows only in the presence of the particular starter bacteria and destroys the cells. The infection in the whey is not serious, but when it gains entry to the starter itself, it can inhibit the development of acidity completely. Where there is phage infection, the milk usually ripens normally, but acidity development ceases during stirring and scalding and may not recommence for 12 hours or more.

It can be controlled by scrupulous attention to the propagation of the starter and especially prevention of all contamination with whey. When the trouble is experienced, it is advisable to obtain an unrelated starter from an entirely new source and to replace the starter at frequent intervals.

Taints in Cheese—These may be due to the use of a contaminated milk or poor methods of manufacture which result in a wet curd. They may also be caused by a weak starter which allows the milk bacteria to gain the ascendancy.

A starter infected with yeasts may give a " yeasty " cheese with evidence of slight gas production.

Floating Curd—This is caused by the coliform organisms which produce lactic acid and the gases carbon dioxide and

hydrogen from milk. These gases become trapped in the curd particles which then rise to the top of the vat and often split through the pressure of gas inside the particles. It is caused by an infected starter or, more frequently, by the use of milk of very poor bacteriological quality.

Colour Faults—" Red spot " in cheddar cheese is caused by a red colour producing organism in symbiosis with other bacteria.

" Mottling " of cheese coloured with annatto may be caused by incorrect acidities.

TABLE 66: AVERAGE YIELD OF CHEESE FROM MILK OF DIFFERENT BUTTER-FAT CONTENTS

Per cent. fat in milk	lb. of cheese per gallon of milk	lb. of cheese per lb. of fat
3·00	0·83	2·77
3·25	0·89	2·75
3·50	0·95	2·70
3·75	1·01	2·67
4·00	1·06	2·65
4·25	1·12	2·63
4·50	1·17	2·59
5·00	1·29	2·58

TABLE 67: COMPOSITION OF WHEY

	Per cent.
Water	93·04
Total solids	6·96
Fat	0·36
Proteins	0·84
Lactose, salts, etc. ...	5·76

BUTTER

Under the Food and Drugs Act, 1938, butter must not contain more than 16 per cent. of moisture. There is no legal standard for salt content.

Butter varies widely in composition. Creamery butters usually contain about 15·5 per cent. of moisture and 1·5–2·0 per cent. of salt, while farm butters are much more variable, containing from 10–20 per cent. of moisture and a variable

proportion of salt. The curd content of creamery butter rarely exceeds 0·5 per cent. but again, farmhouse butter may contain variable amounts, being high in unwashed butters or where the churning process has been carried too far.

The flavour of butter from unripened cream is due to the flavour of the butter fat enhanced by the salt. The " nutty " flavour of butter manufactured from ripened cream is due to the flavour producing substance diacetyl, produced by the starter organisms.

The keeping quality of butter is determined to a large extent by the methods of manufacture. Butter from pasteurised unripened cream keeps for long periods in cold store, while butter from ripened cream, especially if the acidity of the cream at churning exceeds 0·22 per cent. lactic acid, may rapidly develop a " fishy " taint under the same conditions. Infection of the butter during manufacture or from the original cream leads to poor keeping quality, as bacteria, yeasts and moulds cause rapid development of rancidity. The presence of excessive amounts of casein or buttermilk caused by poor methods of churning or washing also reduces the keeping quality, and such butters often become " cheesey."

Manufacture

1. The milk used for butter manufacture should be produced under good hygienic conditions.

2. The cream should be separated from the milk by means of a mechanical separator, as this reduces the losses of butter fat as compared with setting and hand skimming. The cream obtained is also fresh and sweet, and the percentage of fat can be regulated to 30–35 per cent. which is most suitable for churning.

3. **Cream Ripening**—To obtain a good flavoured butter for quick consumption, the cream should be ripened either naturally or by the addition of starter. Natural ripening is carried out by mixing together the cream of two or three days and holding at 56–60° F. for churning on 3rd or 4th day. Natural ripening is not recommended as it may result in butter of poor flavour and keeping quality caused by organisms derived from the milk.

When a starter is used, the cream should be heated to 150–160° F. for 20–30 minutes and cooled immediately to

60–70° F. A small quantity of starter—1–2 per cent.—is then added to the cream, which is then allowed to ripen for about 24 hours at 60° F. If small quantities of cream are separated daily for churning once or twice a week, the first batch of cream should be ripened by using a small quantity of starter—often less than 1 per cent.—and each succeeding day's cream is pasteurised and cooled before stirring into this.

4. **Churning**—Cream may be churned at 57° F., but it is advisable to adjust the temperature of the cream at least three hours before churning, as shown in the following table:—

TABLE 68

Temperature in Dairy °F.	Temperature of Cream °F.
62	53
60	54
58	55
56	56
54	57
52	58
50	59
48	60

The churn should never be more than half filled, and the butter should come in 20–40 minutes. Churning should cease as soon as the butter " breaks." Cold breaking water should then be added and churning continued until the butter grains are of about the size of a mustard seed or slightly larger, but never into lumps.

5. **Washing**—After the buttermilk is drawn off, the grain is washed twice to remove the casein.

6. **Salting**—Mild salting can be carried out by covering the grain in the churn with brine containing 1–2 lb. of salt per gallon of water and allowing the grains to soak for about 20 minutes.

For salt butter, dry salting is usually adopted—$\frac{1}{4}$–$\frac{1}{2}$ oz. of fine, dry, clean salt per lb. of butter being added to the grains immediately after removal from the churn.

7. **Working**—The object of " working " is to remove excess moisture by means of the roller on the butter worker.

This operation should be carefully carried out to ensure a good texture.

8. **Faults of Butter**—*Sleepy Cream*—This refers to cream which adheres to the surfaces of the churn with the result that churning is delayed. It may be caused by milk from cows nearing the end of their lactation, the temperature of the cream being too low at churning, overfilling the churn, or the use of cream which is too thick.

Frothy Cream—May be caused by improper ripening, resulting in the development of yeasts and coliform organisms.

Poor Flavour—Caused by ripening conditions which favour the growth of bacteria other than lactic acid producing organisms. Foods which cause taints in milk may also result in taints in butter.

Colour Defects—Contamination with yeasts and moulds can cause dark green and even pink discoloration of the butter. Streakiness may be due to poor washing of the grain, to over-churning or to lack of care while dry salting.

Proportion of Butter Yielded—Approximately 2½ gal. of average milk containing 3·65 per cent. of fat are required to produce one pound of butter.

USEFUL DATA

Temperatures—

Milk from cow ...	98° F.
Milk uncooled in churn	90–95° F.
Milk separated at ...	90–100° F.
Sterilising	212° F.
Pasteurising milk ...	145–150° F. for 30 minutes.
	161° F. for 15 seconds.
Pasteurising cream ...	155–160° F. for 30 minutes.
Pasteurising milk for starter	180–190° F.

Average freezing point of milk (Hortvet) −0·545° C. (31° F.).

Utensils—All utensils used for milk should be seamless and of a type which can be easily cleaned and sterilised. All metal work should be tinned or made of a metal such as stainless steel or aluminium. Galvanised utensils must never be used.

TABLE 69 : STANDARDS FOR MILK PRODUCED UNDER LICENCE

The general conditions laid down for production of milk are given in the Milk and Dairies Regulations, 1949. In addition, the Milk (Special Designations) (Raw Milk) Regulations, 1949, and the Milk (Special Designations) (Pasteurised and Sterilised Milk) Regulations, 1949, lay down hygienic standards for milk produced under licence.

RAW MILK—LICENCES ISSUED BY THE MINISTER OF AGRICULTURE, FISHERIES AND FOOD

Designation of Milk	Herds	Hygienic Standard	Other Conditions
Tuberculin Tested . .	The herd must be "attested," i.e., all animals in the herd must have satisfied the tuberculin test.	Submitted to a methylene blue test monthly. Shall not decolorise methylene blue in 4½ hours or less in summer (May to October inclusive) or 5½ hours in winter (November to April inclusive) when submitted to the prescribed test. Samples to be stored at atmospheric temperature before carrying out the test for the following periods: Evening milk—until 10 a.m. on the day following production. Morning Milk—until 6 p.m. on the day of production. Mixed Milk—treated as milk from most recent milking.	Must be consigned to the retailer in properly sealed unventilated churns, or must be bottled on the farm. Bottling premises must be licensed.

PASTEURISED AND STERILISED MILK—LICENCES ISSUED BY THE LOCAL LICENSING AUTHORITY

	Heat Treatment	Standards	Other Conditions
Pasteurised and Tuberculin Tested (Pasteurised)	Milk heated to not less than 145° F. or more than 150° F. for at least 30 minutes OR to not less than 161° F. for at least 15 seconds or any other time/temperature combination approved by the Minister of Food.	Must satisfy the prescribed phosphatase test. Must not decolorise methylene blue in ½ hour or less when the test is carried out on milk which has been stored at atmospheric temperature not exceeding 65° F. until 9 a.m. on the day following delivery to consumer.	Premises must be approved and licensed.
Sterilised	Homogenised milk heated in the bottle to not less than 212° F.	Must satisfy the prescribed turbidity test.	Premises must be approved and licensed.

Milking Pails—Most convenient size about four gallons.

Milking Machines—There is a wide variety of bucket type plants. In addition, there is the bail type suitable for milking in the field, and the auto recorder or parlour type which can be used for cows housed in covered yards.

Coolers—A surface cooler of adequate capacity should always be selected so that cooling can take place rapidly. A safe rule is to select a cooler of at least twice the size required.

Mechanical cooling is become more popular, and coolers may be of the direct expansion type (where direct expansion of the refrigerant gives the necessary cooling) or utilise chilled water or brine. The latter use a smaller compressor, as the cold can be stored. In some instances, immersion coolers are recommended, and these have the advantage of reducing the equipment required, as the milk is cooled in the churn.

Milk Cans or Churns—The cans in common use are of 10 and 12 gallon capacity, and must be fitted with a close-fitting, mushroom-type lid. The standard can recommended by the British Standards Institution is of 10 gallon capacity and weighs about 31 lb.

BEEKEEPING

THE Honey Bee is kept predominantly for producing honey, and to a lesser degree wax, but is also very important for pollinating crops.

The Honey Bee, *Apis Mellifera L*, belongs to the Class *Insecta*, Order *Hymenoptera*, family *Apidae*. The Black Bee is native to this country, but with improving standards of beekeeping a more prolific strain of bee was required and in recent years it has been crossed, usually with the Yellow Italian Bee, to give a hybrid kept by most beekeepers to-day.

There are three types of bee found in a colony, the queen, workers and drones. The queen and workers are females and are developed from fertilised eggs. Development into queens is dependent entirely on the treatment of larvae, which are fed solely on a concentrated food known as royal jelly, whereas workers and drones are fed on a similar substance for the first three days, but afterwards on predigested pollen. Royal jelly is believed to be a glandular secretion from the nurse bees. The drones are males, and are developed from unfertilised eggs.

Queens have an average effective life of three years, but prolificacy usually decreases after the first year. Queens lay 1,000–5,000 eggs per day, 2,000 being a good average. If hive conditions and honey-flow are good, the queen usually lays well and after the winter a hive contains 10,000–20,000 bees, but with the commencement of the honey-flow numbers rise rapidly, so that by midsummer the colony strength is up to about 80,000, gradually decreasing during the autumn.

Workers have an average effective life of six weeks in summer, autumn hatched workers surviving the winter, but dying off quickly in spring, when hive activities begin again.

Drones are hatched in summer, and die or are killed off by the workers at the end of the season.

Life history of the three castes in days:—

	Queens	Workers	Drones
Egg hatches	3rd	3rd	3rd
Cell is sealed over ...	8th	8th–9th	10th
Adult emerges	15th–16th	21st	24th

Virgin Queens mate on the 5th–8th day after emergence if the weather is favourable, and lay on the 2nd–3rd day after mating.

BEEHIVES

Modern movable comb hives are based on the observed fact that a space between $\frac{3}{16}$ and $\frac{3}{8}$ of an inch in a hive remains free from wax and propolis. Several types of beehive are in common use to-day and it is advisable to consult local beekeepers on the suitability of these hives for prevailing conditions. Single walled hives, e.g., National and Modified Dadant are favoured by commercial beekeepers, as they are cheaper to buy and are more readily handled. Double wall hives, e.g., W.B.C. are used largely by amateurs, but are losing popularity in milder climates.

Beehives contain two distinct chambers, the brood chamber, which fits immediately on to the floor board and where the queen lays and rears her brood, and the supers which are used to accommodate the honey. Between the brood chamber and supers is a wire framed queen excluder with spacings to permit the passage of worker bees up into the supers, but to confine the drones and queen to the brood chamber. The supers are covered with a quilt or crown board and the whole hive is covered by a waterproof roof. Choice of hive may depend on brood chamber capacity, especially where very prolific queens are kept. The Dadant and Langstroth have a much greater brood chamber capacity than the National, W.B.C. or Smith hives.

Frames are designed to hold the comb, and this facilitates examination of the brood chamber and extraction of honey from the supers. Combs will become old and stale and need replacing. To do this a sheet of wired foundation wax is firmly secured in the frame and the bees are left to draw the wax into cells.

COMMENCEMENT OF BEEKEEPING

A beginner is well advised to get into touch with the County Beekeeping Instructor or the local Beekeeping Association for advice on local conditions and general principles of beekeeping.

TABLE 70: BEEHIVES IN COMMON USE COMPARED ON THE BASIS OF TOTAL COMB AREA IN BROOD CHAMBER

	Total area of comb surface available in Brood Chamber (sq. in.)	Number and types of frames	Single or Double Walled
W.B.C.	2126	10 British Standard	Double
National	2340	11 British Standard	Single
Smith	2340	11 British Standard	Single
Langstroth ...	2740	10 Langstroth	Single
Major British Jumbo	3110	11 British Commercial	Single
Glen	3180	15 British Standard	Double
Modified Dadant	3760	11 Modified Dadant	Single
Buckfast M.D. ...	4100	12 Modified Dadant	Single

The essential equipment is as follows:—One hive, complete with brood chamber, two supers, and the necessary frames fitted with wired foundation and one hive as above without supers. Also required are veil, smoker, queen excluder, rapid feeder, hive tool and small extractor.

Bees are best purchased in early June, as a strong nucleus headed by a young queen. It is advisable to buy from a reputable source. Swarms can be used but there is a risk of disease and an undesirable type of bee may be obtained.

Anyone contemplating commercial beekeeping is advised to spend at least one year on a commercial honey farm. The capital necessary to start a large scale beekeeping concern to-day is quite considerable. At the time of writing it is estimated that a unit of 100 new hives, bees and accessories would require about £1,300 fixed capital with a further £200 working capital for use during the following eighteen months when the first honey crop would be taken. To obtain a reasonable income the number of stocks would have to be increased to about 300, again involving more capital.

The Honey Producers' Association caters for commercial beekeepers who have more than 40 colonies.

Management—For successful honey production certain principles should be followed:—

One of the limiting factors in honey production is the capacity of the flora, and to know the expected times of nectar flow is essential. Closely linked with the above point is the aim of all systems of management to have the colony up to its peak strength at the onset of the honey flow. Unfortunately this is when the colony is most prone to swarm. Hence the success of a system will be judged by the prevention of swarming.

Preventing swarming is one of the most important aspects of management. Swarming is caused by (1) Insufficient space for brood rearing. (2) Poor ventilation. (3) Age and strain of queen.

To prevent swarming it is essential to anticipate the rapid expansion of the brood nest, and to give more room in advance. This is done in several methods of swarm control such as the Demaree and Artificial swarming method. In the former method and its modifications the queen, by means of a queen excluder, separating her from the old brood nest, is confined to a new brood chamber with empty combs. In an artificial swarm the queen is put into a new brood chamber with empty combs and housed on the old site, while the young bees and brood are housed on a new site and reunited at a later stage.

Ventilation can be improved by removing heavy quilting in summer. Hives may be painted white to reflect the sun's rays rather than absorb heat.

As young queens are less inclined to swarm, requeening annually from a stock which tends to supersede rather than swarm will help to reduce swarming.

Sugar Feeding of Bees—Because of the relative prices of sugar and honey, it pays to take away most of the honey, replacing the winter stores with sugar. A rapid type of feeder should preferably be used. For feeding, dissolve 2 lb. of sugar in one pint of water. A minimum of 35 lb. of sealed stores is essential for the successful wintering of a colony.

In spring, if the commencement of the honey flow is late, and stores are dwindling, sugar solution may be fed both as a source of food and a stimulant to brood rearing.

Provision of drinking water—As water is essential to hive life, the provision of clean drinking water near the hive is essential.

Finding the Queen—Normally the queen is found by a systematic examination of the brood chamber. If this method fails, the following procedure may be adopted. After placing a frame of emerging brood into a hive containing empty frames, shake the rest of the bees into the new hive and move it to a new site. The older flying bees return to the old site, leaving the queen and young bees behind. Usually the queen is now easily found.

Tests for queenlessness—Place a frame of 3-day old eggs into a colony and leave for three days before examining for queen cells. If any are found, generally no queen is present.

Queen Introduction—A new queen may be introduced directly with a nucleus. The method of individual introduction involves putting her in a special cage which is placed in the centre of the brood nest after the reigning queen has been found and destroyed. In the cage is a hole plugged with candy, leaf or some material which can be removed by the bees. By the time the hole has been cleared and the queen released, the bees will have accepted their new queen.

Uniting of bees—Occasionally two stocks of bees may need to be united. If each stock has a queen, one of the queens should be destroyed and the queenless stock placed above the queened stock with two sheets of perforated newspaper separating them. The bees eat through the paper and accept one another. This operation is best undertaken late in the day. A few days later the bees can be put down on to one brood chamber.

Honey—Nectar is collected as a watery solution of sugars which is " inverted " by the bees to a mixture of levulose and dextrose. The mixture is concentrated by the evaporation of moisture and stored in the cells of the comb. Average density of honey is 1·416 at 60° F.

Honey plants—White clover is an outstanding yielder over a wide range of conditions and is the principal honey crop in most areas of Great Britain, whilst lime is important in the urban areas. Heather is limited to special areas and forms a most valuable late crop, generally extending from early August to late September. Fruit blossom, charlock,

sainfoin, mustard, field bean, sycamore, blackberry, willow herb, hawthorn and dandelion are also useful sources.

Yield of Honey—The average yield of surplus honey is 25–30 lb. per hive, though in favourable seasons some bee-keepers may achieve an average approaching 100 lb. per hive.

Pollen—Contains both proteins and vitamins necessary to the bees as a source of food, and is essential for brood rearing.

Pollen plants—Gorse is a good all-the-year-round source but is an especially valuable early spring source, as are hazel and poplar trees. Ivy is an important late source. There are also many minor sources like larch, privet, plantain and cocksfoot.

The use of the honey bee for pollinating crops—Fruit and seed owners have in recent years realised the importance of successful pollination, and have been prepared to pay £1–£3 for hives of bees transported to their crops when in flower. Many fruits cannot set fruit with their own pollen and have to be cross pollinated, e.g., many varieties of apples, pears, plums, and cherries. Clovers and Brassicas grown for seed and soft fruits benefit considerably if well served by bees.

One strong colony per acre is generally considered sufficient for pollination purposes. The best results are usually obtained by waiting until just after the onset of the main flowering period before importing the bees, as they are less likely to wander from the crop.

BEE DISEASES

Adult Bee Diseases

	Symptoms	Causative Organism	Control
Acarine	Weak crawling workers often with swollen abdomens and unhooked wings	Acarapis woodi. A parasitic mite present in the anterior thoracic breathing tubes	Use of sulphur fumes or Methyl salicylate
Nosema	Dwindling colonies, some showing dysentery, greyish white appearance of intestines	Nosema apis, a protozoan parasite	Only preventative control is possible, e.g., isolation on infected colonies

Brood Diseases

American Foul Brood	Kills and decomposes larvae after cells have sealed over. Sunken and perforated capping, distinctive odour	Bacillus larvae a spore forming bacterium	Colonies must be destroyed under Foul Brood Order, 1942. Infected combs and bees must be burnt and hives disinfected
European Foul Brood	Death of unsealed larval stages—they are often turned around in their cells before decay is pronounced	Appears to be related to the Bacillus pluton, a spore forming bacterium	As for A.F.B.

Treatment for Acarine Disease—Sulphur fumes are obtained by burning cardboard impregnated with sulphur in a smoker. A few puffs are given at the entrance each evening for three successive days and this is repeated after a five-day interval.

Methyl salicylate, or Oil of Wintergreen, is best used in the warmer months and is administered by placing a small tube containing the chemical absorbed in cotton wool on the floorboard of the hive.

N.B.—Only young bees up to five-days old can be infected with the mite.

Hive Disinfection—The blow-lamp should be used for this purpose, and where this is not possible the following solution:—Washing soda—1 lb., ½ lb. bleaching powder, 1 gallon hot water should be scrubbed in and thoroughly washed out.

Diagnosis of Bee Diseases—Samples of bees and brood in England and Wales can be examined for disease free of charge. Samples of not less than 30 bees or one brood comb should be securely packed and sent to the Chief Bee Advisory Office, National Agricultural Advisory Service, Rothamsted Lodge, Hatching Green, Harpenden, Herts.

GENERAL INFORMATION

British Standards Institution Definitions regarding Sale of Bees.

(*a*) **Stock**—The term " stock " should be used to denote a colony of bees offered for sale together with the hive.

(*b*) **Colony**—The term " colony " denotes a colony of bees occupying not less than six 14 in. by 18½ in. combs. In the case of 16 in. by 10 in. or 14 in. by 12 in. combs, not less than four combs are required.

(*c*) **Nucleus**—The term " nucleus " denotes a quantity of bees occupying not more than five 14 in. by 8½ in. combs or three of the large combs referred to in (*b*) above.

(In (*b*) and (*c*) the number of combs shall be stated in each case.)

MACHINERY

TRACTORS

THE size of a tractor is usually indicated by quoting its maximum belt h.p. which is the power available to the user at the pulley of the machine to be driven; it is less than the flywheel, i.e., brake h.p. of the tractor engine. This is due to losses in the gears to the tractor belt pulley and in flexing the belt.

The modern tractor is usually available with alternative engines for petrol, vaporising oil and diesel fuels. The maximum power per 1000 c.c. of the cylinder capacity averages approximately:

Fuel	Belt horse-power/1000 c.c.
Petrol	13·6
Vaporising Oil	11·0
Diesel	10·8

The compression ratios used are, approximately, petrol 6 : 1, vaporising oil 5 : 1, diesel 16 : 1. Largely due to the appreciably higher compression ratio of the diesel engine it is more efficient in converting fuel to useful work. The average specific fuel consumptions are:

Fuel	Pints/ belt h.p. hr.	lb./belt h.p. hr.	Belt h.p./ hr./gallon	Specific gravity of fuels at 60° F
Petrol ...	0·65	0·58	12·3	0·717
Vaporising Oil	0·70	0·72	11·5	0·823
Diesel ...	0·44	0·46	18·1	0·829

The maximum h.p. developed at the drawbar will be less than the belt h.p. due to the frictional and churning losses in the transmissions, slip of the driving wheels or tracks and the tractor's own rolling resistance.

For tractors which develop 50 h.p. at the flywheel approximate values for the maximum h.p. developed at the various points of usage are:

Belt h.p. with side mounted pulley	45
Belt h.p. with rear mounted pulley	43·5

H.p. when directly coupled to power take-off shaft	46
Drawbar h.p.	40

The gear in which maximum drawbar h.p. is developed depends on the gear ratios, land conditions and the wheel or track equipment. A conventional tractor on unballasted pneumatic tyres working on stubble and having five forward gears would probably develop maximum drawbar h.p. in 3rd or even 4th gear. The addition of ballast or a strake device to the wheels reduces slip in the lower gears and hence the power in 2nd gear is increased and probably equals the power previously available in 3rd gear; the maximum power developed in the highest gear is reduced due to higher rolling resistance. The tracklayer, because of lower slip at high pulls and higher rolling resistance absorbing power, may be expected to develop maximum power in 1st or 2nd gear. The ratios between maximum drawbar h.p. and belt h.p., overall weights and maximum pull are shown in detail on four types of surface in the Table below.

		*B.S. test surface tar-macadam	Grass-land on clay	Stubble on medium loam	Loosely cultivated medium loam
Wheeled tractors					
Maximum drawbar h.p. expressed as a percentage of max. belt h.p.	1st	65	54	44	37
	2nd	83	70	60	52
	3rd gear	84	73	67	57
Ratio of maximum sustained pull to overall weight		0·72	0·64	0·57	0·53
			*B.S. test surface		
Tracklaying tractors					
Maximum drawbar h.p. expressed as a percentage of max. belt h.p.	1st	—	76	65	56
	2nd	—	81	79	72
	3rd gear	—	74	72	64
Ratio of maximum sustained pull to overall weight		—	1·06	0·92	0·84

* These conditions are those used for tests made in accordance with British Standards Specifications.

The maximum pull of a tractor having pneumatic tyred wheels is largely dependent upon the actual weight on the driving wheels. There is a weight transference from the front wheels to the rear wheels due to the drawbar pull. For horizontally applied drawbar pulls:

Approximate weight transfer (lb.) from front to rear wheels:

$$\frac{\text{pull} \times \text{drawbar height (in.)}}{\text{wheelbase (in.)}}$$

The ratio of maximum sustained pull to live (i.e., actual) weight is higher than that shown for the gross weight ratio in the above table. The addition of ballast to the rear wheels has the following effect:—

	Tar-macadam	Dry grass-land	Dry stubble on medium loam	Cultivated medium loam
Increase in pull expressed as a percentage of the added weight	80–85	70–75	65–70	55–65

Tractor power take-off shaft speed should be 540 r.p.m. ± 10 r.p.m. at the engine speed recommended for p.t.o. shaft work. It should, however, be noted that this is not always the maximum speed at which the engine can be operated; higher engine speeds are often recommended for drawbar work when it is independent of machines operated from the p.t.o. shaft.

The linear belt speed should be 3100 ± 100 ft. per min. at the engine speed recommended for belt work. This also need not necessarily be maximum speed at which the engine can operate.

These constructional recommendations, together with details of the drawbar, p.t.o. shaft and guard, belt pulleys, fixing dimensions of front wheels, and tyre sizes for light and medium agricultural tractors are given in British Standards Specification No. 1495 : 1948.

Other British Standards Specifications relating to tractor

details and the measurement of their performances are as follows:

B.S. 2596 : 1955	Components of crawler tractors and earth moving equipment.
B.S. 1701 : 1950	Air filters for internal combustion engines and compressors.
B.S. 2800 : 1957	Tests for industrial crawler and wheeled tractors.
B.S. 1773 : 1951	Hydraulic lifts for agricultural trailed implements.
B.S. 1841 : 1951	Attachment of mounted implements to agricultural wheeled tractors.

PLOUGHS

There are two main kinds of plough used throughout the world—the mouldboard and the disc. The former is used almost exclusively in Britain and north western Europe because it inverts the furrow slice and gives good weed control in the prevailing climate. The disc plough cannot normally invert the furrow slice completely, but leaves roughly broken soil and partly exposed trash—a type of cultivation which is held to be suitable for extremes of climate in the New World and in places where the hot sun kills weeds in the furrow slice and rain and wind erosion are reduced by the broken surface and exposed trash. A higher forward speed is often practicable for a disc plough and it can ride over obstructions with less chance of breakage.

MOULDBOARD PLOUGHS

The body and particularly the mouldboard characterise the plough. There are many shapes of mouldboard (or breast) available, but most of them can conveniently be classified into three groups:

General purpose (G.P.)—Gradual twist; surface slightly convex; maximum ploughing depth about 8 in.; turns furrow slice with width to depth ratio of not less than $1\frac{1}{2}$ to 1 respectively; "sets up" relatively unbroken furrow slice; useful for autumn ploughing; also for grassland. The "lea" mouldboard is a specialised example in this group with long gently twisted shape. It is designed for grassland

ploughing to set-up unbroken furrow slices, but is rarely used except in ploughing matches.

Semi-digger (**S.D.**)—Sharper twist and deeper than general purpose type; slightly concave surface; maximum ploughing depth about 12 in.; turns furrow slice with width to depth ratio of less than $1\frac{1}{2}$ to 1; a rather broken furrow slice; useful for ploughing at all times.

Digger (**D.**)—Sharp twist and deep, with cut-away bottom edge; concave surface; maximum ploughing depth according to size of body; down to 20 in. if required; turns furrow slice with width to depth ratio of 1 to 1; very broken furrow slice; useful for spring and autumn ploughing when immediate planting of crop is required; an almost flat seedbed can be produced in light land by ploughing shallowly at speed; not very suitable for ploughing grassland.

Shares—The shape of a share is determined largely by the type of body to which it is fitted, but there are variations in shape often available, particularly as regards the point and the width, which are designed to fit any one type of body.

Shares for G.P. bodies—7–10 in. wide; chisel-pointed for general use; usually of chilled cast iron for cheapness; also of steel to avoid fracture in rocky conditions.

Shares for S.D. bodies—Up to 12 in. wide; often 2-piece, point and wing, when usually of chilled cast iron; also chilled cast iron and steel one-piece shares are used.

Shares for D. bodies.—Width according to size of body; usually one-piece steel shares; expensive.

Bar-point share—This type of share, mostly used in Scotland, is useful for stony conditions, having a longer life and probably being more economical than others in abrasive soils. A 20-in. bar of high quality steel is taken through the wing to form the point and can be adjusted and turned over as the point wears. This share deserves to be far more widely used.

Hard-surfacing materials—The welding of these materials on the points and wing edges is practised on steel shares to obtain longer life; but on cast-iron shares the operation is not usually economically justified.

Coulters—Disc (or rolling) coulters are now most widely used. Their chief advantage over knife coulters is the ability to cut through trash. They can be set fairly deep in soft land but should be set back and high in hard or stony land which is difficult to penetrate, as otherwise they tend to hold the plough out of the ground. The knife coulter has advantages under these circumstances because it can be inclined backwards from the point so that it enters the ground at a suitable angle.

Wavy-edged and cut-away discs are sometimes used as being more effective than plain discs in cutting through trash.

Skim Coulters—(" Skims ") are designed to skim off the corner of the furrow slice and to place it in the bottom of the furrow so that no trash is left showing on the surface. Other devices such as chains trailing over the furrow slice and trash guards are sometimes used but are not fully effective in avoiding blockages when ploughing in long " combined " straw.

DISC PLOUGHS

These are of two main types:

(*a*) the normal disc plough, with discs from 26 to 32 in. diameter which are individually mounted and individually adjustable for angle, is used for the deeper work.

(*b*) the harrow disc plough (or wheatland plough), with discs from 20 to 26 in. diameter mounted on a common axle, is used, as its name implies, for wheat land and often carries a seedbox so that cultivation and sowing are done as one operation.

The working angle of the discs on both kinds of plough is usually from 35 to 45 degrees, and different total widths of cut can be obtained by changing the angle of the whole plough to the direction of travel. The lateral thrust of the discs is counteracted by the wheels which are therefore mounted " off vertical." A scraper for each disc keeps it clean and helps to invert the soil.

Although the disc plough is often said to be capable of better penetration and to be of lighter draught than the mouldboard plough, there is some doubt about these statements and little evidence to support them.

TRAILED AND MOUNTED PLOUGHS

Large heavy ploughs are still of the trailed type. Mounted ploughs have now become popular, but the capacity of the tractor lift units limit the size of the plough which can be handled. Their handiness for headland turns and for awkward corners is obvious.

Trailed ploughs are made in up to 6-furrow units, whereas mounted ploughs are made in up to 4-furrow units. It is usual to be able to reduce the width of ploughing by removing one body and/or, in some cases, by adjusting the beams or legs and reducing the width of each furrow.

Semi-mounted ploughs are available. These may be carried on the tractor drawbar at the front and on twin caster wheels at the rear. In this way they may transfer weight to the tractor wheels and so increase their adhesion.

REVERSIBLE PLOUGHS

These are mainly mouldboard ploughs fitted with both right-hand and left-hand bodies. They are also termed " one-way " ploughs in Britain and " two-way " ploughs in America. The confusion arises because all the furrows are turned " one way," but at the same time the bodies are left- and right-handed, hence " two-way."

The advantages of these ploughs are that only headland marks are required and the field surface is left flat. However, a rather wider headland is usually required, and their initial cost is greater. " Balance," " Turnabout," " Turnover," " Roll-over," " Turnwrest," were names given to reversible horse ploughs with different body or mouldboard change-over arrangements.

DRAUGHT

Soils are often grouped according to the resistance they offer to the passage of a plough through them. The term " soil (or " ploughing ") resistance " is often used in this connection.

To estimate the size of plough to use with a particular tractor, the drawbar pull of the tractor at ploughing speeds and on different surfaces must first be known and the soil resistance estimated. For example, assuming a drawbar

pull of 2000 lb. to be available and the land to be of medium loam with a soil resistance of 10 lb./sq. in., then a total area of $\frac{1 \times 2000}{10} = 200$ sq. in. of furrow slice cross section could be ploughed at once. Therefore, at, say, 5 in. deep, the ploughing would be $\frac{200}{5} = 40$ in. wide. Thus, at this depth a 4-furrow plough with 10-in. furrows could be used. In practice in such a case a 3-furrow plough with 10- to 12-in. furrows would probably be chosen so that an allowance would be made for extra depth if required, or for soil variations in the field.

OTHER CULTIVATION IMPLEMENTS

CULTIVATORS

Tined cultivators may be classified according to tine design, total weight and clearance under the frame, and type of point. Trailed and mounted models are available and, since the inclination of the points secures good penetration, wheels are fitted to control depth unless (in mounted versions) the linkage of the tractor is arranged for this purpose.

Rotary cultivators at the present stage of development follow a common broadly similar design, the main difference being one of size.

Rigid Tines—For heavier work, available in widths up to about 9 ft. and weighing up to 300 lb. per tine. About 80 lb. per tine is more usual for lighter work. Tine spacings can be adjusted and extra tines fitted. Spacing may be as close as 6 in. for clean land or as wide as 12 in. under trashy conditions. The effective tine length can be up to 24 in., but for normal work 18 in. is adequate.

Spring-loaded Tines—For use in stony soils or soils overlying rock. Different tine arrangements are available using compression or tension springs to load the individual tines which can move upwards and backwards when an obstruction is met.

Spring Tines—The tines are made of curved spring steel which is sometimes formed in an extra coil to give increased elasticity. Useful for bringing " couch " or " twitch " to

the surface the tines keeping relatively free from blockage because of the vibration as they move through the soil.

Points—Replaceable points are invariably used. The reversible point, about 2 in. wide, is most economical and widely used. Other points of different shapes and increasing widths are obtainable, being used to ensure cutting weed roots, and, under certain circumstances, to leave a stubble mulch.

Draught and Rate of Work—The draught of a medium-sized cultivator varies widely according to soil conditions and depth of work, 1500 lb. being regarded as a "middle" figure. Soil surface conditions during this work are not usually suitable for good tractor wheel adhesion. A rate of work of about $1\frac{1}{2}$ acres per hour may be expected from an 8 ft. implement.

Rotary Cultivators—Trailed and mounted models are available up to 6 ft. in width, driven either from the tractor p.t.o. or from an auxiliary engine. The axis of the rotor is usually horizontal, and L-shaped blades are used for general purposes. "Pick" tines for hard or stony land and other tine patterns for special jobs can be obtained.

Since the rotor tends to propel itself, there is little or no drawbar pull to be exerted by the tractor. Work can be done to a depth of 10 in., but normal cultivations seldom exceed 5 in.

The power requirement is high, particularly in hard unploughed land; a figure of 6 h.p. per foot of width may be taken as a guide, although wide variations in power requirement occur according to soil conditions.

HARROWS

Rigid-tined (also Spike-toothed, Zig-zag, etc.) Harrows—These may be grouped according to size, shape and weight of tine and to the width of track of the tines. The terms "zig-zag" and "diamond" refer to the design of the frames.

Heavy harrows are fitted with curved tines ("drag" harrows); they are also fitted with straight tines up to 9 in. long, weigh 6 lb. (or over) per tine, and make tracks 3–4 in. apart. Medium harrows have straight tines up to 8 in. long and weigh 3–5 lb. per tine. Light harrows have straight

tines up to 6 in. long and weigh up to 3 lb. per tine. Narrower tracks of $1\frac{1}{2}$ to 2 in. are more usual for the lighter harrows. The number of teeth fitted varies from 15 to 25.

Another version of a rigid-tined harrow is the "Dutch" harrow having a heavy timber frame with tines fitted top and bottom, each set of different length. The timbers have a levelling and scrubbing action hence the implement combines the functions of harrow and scrubber.

The saddle-back harrow is yet another specially designed harrow used in units, each of which is shaped to a curve to work on the sides and top of a potato ridge.

Grassland Harrows—According to the severity of treatment required, chain harrows, flexible harrows with spikes and with replaceable blades, and self-cleaning turnover harrows are available in widths made up of single or combined sections up to approximately 20 ft.

Disc Harrows are widely used because they create a tilth without dragging up trash buried by the plough and consolidate the ground whilst at work. The same general design is used for construction of the disc gangs although the gangs are arranged differently for different purposes. The tandem arrangement with 2 sections forward and 2 at the rear is best known in Britain, but off-set 1-section gangs in tandem are available for orchard work. The discs vary in diameter from 18 in. to 24 in. with spacings between them of 6 to 9 in. The draught of an 8-ft. disc harrow is about 1600 lb.

ROLLS

There are two important types: the Cambridge and the flat roller. The Cambridge roll, with its separate rings and ridged periphery, is more generally used. The diameter of the rings varies from 18 to 24 in. and the width of each ring 2 or 3 in. These rollers weigh from 2 to 4 cwt. per foot of width and may be obtained in units to cover a number of widths according to the capacity of the tractor.

The flat roll varies in diameter from 16 to 30 in. and weighs between 1 and 2 cwt. per foot of width. It is best made of short separate cylindrical sections to avoid scrubbing the crop during a turn.

MANURE HANDLING

LOADING

Types of manure loading equipment include:

1. Front-mounted tractor loaders (the most popular type).
2. Rear-mounted tractor loaders (less versatile but more compact design).
3. Cable-fork and conveyor loader (suitable for cleaning boxes and confined spaces).
4. Jib cranes (generally tractor-mounted).
5. Dragline excavator with manure fork (as used by some contractors).
6. Fixed cowshed gutter cleaners (usually electrically driven, feed to trailer).
7. Front-mounted scraper used to push manure out of channels in specially designed buildings, e.g., for pigs.

Front-mounted Loader—Bucket capacity is 3–6 cwt. with a rate of work (depending on layout) of 5–12 ton/hr. (one operator). By comparison one man can hand fork about 2 tons per hr. This machine is one of the cheapest and may have attachments for roots, hay sweepi g, gravel, soil, or bales.

It requires only one man but is not suitable for confined spaces and yards must have a reasonably firm bottom. Weights or water ballast is usually added to counteract the loss of weight on the rear wheels due to weight transfer. They are usually hydraulically operated and the pipe system should be checked for leaks. The rams must be smooth or the glands will be damaged. Dig manure by working from the top of the heap downwards and build load on to spreader starting at the front. During temporary storage leave free of manure, and in the lowered position. At the end of the season clean thoroughly, check pivots and protect rams by seeing they are totally enclosed by the cylinders. Fit screw caps to close oil lines.

Cable-fork and Conveyor Loaders—These score in confined spaces. They require two operators as a rule and the fork operator has a strenuous job. Rate of work com-

parable, but somewhat less than front-mounted loader. The elevator section can also be used for sacks, bales, etc.

Front-mounted scraper to push manure out of buildings—Thought given to designing buildings for easy mucking-out is amply repaid. For example, cowshed with twin adjacent dung channels should be designed wide enough and with wide doors each end to allow tractor to run through. Cleaning can be achieved in very few minutes and if a ramp or sunken road is available, trailers or spreaders can be loaded directly.

MANURE SPREADERS

1. Trailer spreaders with rear beaters (land wheel or p.t.o. driven) most popular.
2. Trailer spreaders with front beaters (generally p.t.o. driven).
3. Field heap spread (p.t.o. driven).
4. Rotating disc spreader (towed behind a trailer).

Trailer Spreaders—These consist essentially of a self-emptying trailer (a slat conveyor is fitted in the bottom) to the rear of which is fitted a set of rapidly rotating beaters. Application rate is adjusted by altering the speed of the conveyor (and tractor speed with p.t.o. machines). Front beater models have the advantage that they are easily used for ordinary transport when not on muck work. The p.t.o. driven types are more versatile as they can be used when the ground surface is slippery; a drive of this type is common on large spreaders. Evenness of spread is better than hand work.

Capacities	$\frac{3}{4}$ to 4 tons.
Speeds	$2\frac{1}{2}$ to 5 m.p.h.
Application rates	4 to 25 tons/acre.
Time to empty	2 to 6 min.
Width of spread	6 to 15 ft.

The rate of work depends upon the length of haul and the arrangements for filling. Before work check that beaters rotate freely and conveyor mechanism is operating. Grease regularly, particularly the high speed rotors. Successive

bouts must be overlapped slightly to give even spread. One typical load put over a weigh-bridge enables actual application rate to be calculated.

Application rate tons/acre =

$$\frac{\text{wt. of load (tons)} \times 4840 \times 3}{\text{distance run per load (yd.)} \times \text{width of spread (ft.)}}$$

Leave unloaded overnight. At the end of the season scrub out with hot soda solution ($\frac{1}{2}$ lb. to 10 gal.). Cresote or paint all woodwork and paint the steel frame. Jack up to take the weight off pneumatic tyres. One of the most efficient ways of using the spreader is the one-man system which employs an easy-hitching trailer spreader. Rates of work of 3 tons/hr. can be achieved with a $\frac{1}{4}$-mile haul.

Unless two spreaders are available two or more men are difficult to employ efficiently. The alternative is a loader and trailer and a field heap spreader.

Field Heap Spreaders—The tractors must straddle small heaps. Evenness of spread as good or better than hand work.

Rate of work	20–30 tons/hr. or 3–4 acres/hr.
Width of spread	15–30 ft.
Speed	3–4 m.p.h.

Rotating Disc Spreaders—Facilitate hand spreading direct from a trailer. Evenness of spread generally poor, but depends on those forking.

FERTILISER DISTRIBUTORS

Three types are in common use: plate-and-flicker, reciprocating plate, and spinning-disc type distributors. Others available have brush or agitator types of gravity feed mechanisms, or various types of moving apron or rising hopper feed mechanisms.

The ever-increasing use of granular and free-flowing fertilisers has made it possible to produce machines employing simple gravity feed mechanisms. Such mechanisms are in common use only on spinning-disc type distributors at present.

Plate-and-flicker Machines—These have the advantage of reliability and versatility in sowing all types of fertiliser, and have a good performance as regards evenness of spread. Although severe bumps cause fertiliser to shoot off the plates, they are otherwise not very susceptible to vibration or changes in the condition of the fertiliser. The rate of application often varies, however, to some extent when working on slopes of over 1 : 10 to 1 : 8.

A machine with a spreading width of 8 to 10 ft. has a rate of work between 1½ and 3 acres/hour depending upon the type of fertiliser, rate of application and field conditions.

Reciprocating-plate Machines—Because the plates are more easily damaged, these usually require more careful maintenance and storage than the plate-and-flicker type. They are more susceptible to the condition and type of fertiliser and are affected by vibration to a greater extent. When operated correctly, the evenness of distribution is very good and the rate of work is similar to that of a plate-and-flicker machine.

Spinning-disc Broadcasters—These are cheap, simple to clean and maintain, and have a high rate of work. The evenness of distribution is not so good as with other types of machine. They are also more difficult to set and use, since to obtain even distribution it is necessary to overlap successive bouts. The optimum bout width is difficult to assess and varies from one type of fertiliser to another. The width of spread varies between 15 and 45 ft. (depending on the make of machine and type of fertiliser) and it is impossible under many conditions to maintain an even bout width without the use of markers.

The rate of work varies between about 3 and 8 acres/hour, being determined by the application rate (which determines frequency of filling), type of fertiliser, and size of field.

Operation—When machines have not been used for a week or two, turn the mechanism over by hand before starting work to ensure it is running freely. To check whether or not the machine is delivering fertiliser at the correct rate, either rotate the mechanism whilst stationary and weigh the fertiliser delivered after turning the mechanism a known number of times; or measure the distance travelled when spreading a known quantity of fertiliser and then

calculate the application rate per acre from the formulae given on page 561.

With many types of machine, and particularly those having gravity feed mechanisms, the application rate varies to a considerable extent with the type and condition of the fertiliser, and a quick check often saves time or wastage of fertiliser in the field.

Any distributor should be emptied at the end of the work, and if it is to be stored away for more than a few days, should be thoroughly cleaned and washed out and then lubricated. (Greasing tends to force out any water entering the bearings.) For long-term storage the use of an appropriate rust preventive is recommended.

SEED DRILLS

The utilisation of a seed drill is largely determined by the type of seed feed mechanism employed. Those in general use may be classified as in table 71.

The feed mechanism of most drills is situated in the base of a common seed hopper, which is carried across the width of the drill frame, and it meters seed to the coulters via the seed tubes. The frame is carried on land-wheels one, or both, of which drives the feed mechanism through a change-speed gear system. Combine drills possess an additional hopper and separate feed mechanism to deliver fertiliser to the coulters with the seed or beside the seed in the ground.

A 6- or 7-inch coulter spacing is used on universal and cereal drills and alternative row widths may be obtained by blocking intermediate coulter feeds.

Unit drills, usually with brush, agitator, or cell feed mechanism, are used for root and horticultural crops. They are mounted in multiples on a tractor toolbar so providing a wide range of obtainable row widths, but each unit is essentially an independent single row drill.

Coulters—Disc: Give good penetration and are not easily blocked. Widely used for cereals, but may give an irregular depth of drilling on stony land.

Shoe: Give a more even depth of drilling in stony conditions than discs, but penetration is not so good and they are more easily blocked. There are many local variations within this type.

TABLE 71: TYPES OF SEED DRILL

Feed mechanism	Utilisation	Comments
Internal force feed	Cereals and larger seeds, e.g., mangolds	Even seed delivery. Drilling rate little affected by ground surface, slope or speed. Seed rate not always easily changed.
External force feed	Universal	Very even seed delivery. Drilling rate little affected by ground surface, slope or speed. Seed rate changed easily.
Cup feed	Universal	Irregular seed delivery at low rates. Drilling rate affected considerably by ground surface, slope and speed. Seed rate only changed with difficulty.
Brush feed	Smaller seeds	Seed delivery not always regular at low rates. Drilling rate affected considerably by speed. Seed rate easily changed.
Agitator feed	Most crops other than cereals. Widely used in horticulture.	Similar to brush feed. Tendency to crack peas and beans.
Cell feed	Mainly beet and brassica crops. Often termed "precision" drills	Even seed delivery at low rates. Individual seeds carried in cells in vertical or horizontal plates or belts—different plates or belts needed for each seed rate and type. Speed limited to 2½ m.p.h.

Operation—The number of rows drilled should be the same as that to be worked subsequently with row crop equipment, or an exact multiple of that number.

Where possible, coulters should not be run in tractor wheel marks. Offset the drill if necessary after setting the tractor wheels to the required spacing. A headland three or four drill widths round the field should be drilled before starting across a field. A high speed of travel reduces the drilling rate and blockages may result if coulters are not lifted when turning or backing.

Markers should be set by measuring the lateral distance

from the centre of the front tractor wheel to the outside coulter of the drill. Add one row width to this figure and set the markers at this distance beyond the outside coulters.

Data and Formula—The draught of drills averages 50 lb. per coulter but varies from 30 to 70 lb. depending on soil.

The average rate of drilling is 0·2 acre per hour per foot of width drilled.

When calibrating any drill (seed or fertiliser) the number of turns of the land-wheel required to drill the equivalent of 1/10th acre is:—

$$\frac{1400}{\underset{\text{(in feet)}}{\text{sowing width}} \times \underset{\text{(in feet)}}{\text{diameter of land-wheel}}}$$

Alternatively one can use the method:—

$$\text{Distance run (yd.) to discharge 1 cwt.} = \frac{4840}{\text{cwt./acre} \times \text{width of spread (yd.)}}$$

PLANTERS

Hand Operated—Potatoes or plants are placed in the furrow by operators seated on a light tractor-drawn frame or mounted toolbar. The required spacing is usually indicated by a clicker or bell driven from a land-wheel.

Semi-automatic—Potatoes or plants are placed in the soil mechanically but both have to be fed on to conveyors by hand, the potatoes into cups and the plants between sprung fingers.

There are also a few fully automatic potato planters in which the conveyor cups pick up " setts " in passing through the hopper. An operator is necessary to correct misses or doubles.

All potato planters except the simplest of hand operated types, which work on previously ridged land, work on the flat. They open a furrow to receive the potato then set up a ridge to cover. Transplanters cut a narrow furrow into which the plants are set then close it around the plants with angled press wheels.

Data—Tractors for use with all except fully automatic potato planters should be capable of operating at speeds down to 1 m.p.h., although with transplanters the speed employed depends on the required spacing of the plants within the row. It may be as low as 0·5 m.p.h.

Each operator can set 75 potatoes or 25 plants per minute with the hand operated planters and 120 potatoes or 50 plants per minute on semi-automatic machines. A fully automatic 3-row potato planter with one operator in addition to the tractor driver will set approximately 1 acre per hour including refilling and turning time.

SPRAYING

Group crop sprayers are broadly divided according to application rates:—

Low volume sprayers	...	Up to 20 gallons per acre
Medium „ „	...	20–60 „ „
High „ „	...	60 and over „ „

Machines capable of covering the complete range of application rates are available.

Sprayer tank capacities range from 30 to over 300 gallons. Low volume sprayers have tank capacities at the lower end of the scale and are usually tractor mounted. Some 100 gallon machines, and all over this capacity, are trailed.

The majority of sprayers utilise a boom covering full width of swath (varying from 15 to over 40 ft. wide) and fitted with nozzles at approximately 18 in. intervals. One new introduction is the wide angle nozzle which does away with a boom or at least requires only a very small one.

Some sprayers can be used for row-crop work: this involves change of wheel-track of trailer versions and fitment of drop legs and adjustment of nozzle spacing where underleaf spraying is desirable, e.g., spraying potatoes against blight.

Two types of nozzle in most common use are "fan" and "hollow cone." These terms describe the shape of the spray leaving the orifice. Fan-type jets made in brass or ceramic material (in case of blockage a very small piece of wood and not a pin or wire must be used to clear this latter type) are in general use for low volume work. Hollow cone nozzles tend to be used for higher volumes.

Application rate is altered by changing nozzles and some fine adjustment is effected by changing pressure (output is approximately proportioned to $\sqrt{\text{pressure}}$). Pressures outside the recommended range for a particular nozzle should be avoided. Excessive pressure produces more fine droplets and increases drift. For fan type nozzle 30–100 p.s.i. is a common working range. The minimum rate usually recommended for herbicides is 10 gal./acre. A speedometer is advisable for all spray work because application rate is directly related to speed.

Sprayer pumps are generally p.t.o. driven. Gear and roller vane pumps are general on low and medium volume machines. On high volume machines the choice is widened with the inclusion of piston pumps, the latter being more suited to pumping suspensions because of the wear resistance of the ceramic cylinder/flexible plunger combination, which is generally used.

Choice of Sprayer—Base choice on acreage of work at high (DNC, copper sprays), medium (DDT) or low (MCPA, 2,4-D, CMPP) volumes. If a small acreage of the dangerous toxic sprays are involved, this work can often with advantage be given to a contractor.

One survey suggests 30 acres per annum of low volume work justifies the purchase of a machine. A tank with good galvanised lining is suitable for most chemicals currently in use, except sulphuric acid (note: concentrated sulphuric acid is less corrosive than dilute), provided it is thoroughly washed immediately after use. Baked on synthetic tank linings are also very good.

If heavy suspensions are used good agitation is essential; mechanical agitation is best. If hydraulic agitation is used the pump must deliver more liquid (perhaps 25 per cent.) than required for application of the spray.

Attachments—Hand lances for fruit tree spraying or spot application on crops. Tractor wheel guards (spats) for row-crop work. Drop legs for under-leaf spraying. Self-filling attachments for drawing water from ponds or streams.

Operation—Check cleanliness of all filters and see no nozzle orifices are damaged. Nozzle wear is initially invisible, and to ensure good quality work tips should be changed every 2 or 3 years regardless of their appearance.

Select suitable nozzle size and pressure from manufacturers' tables. Fill sprayer with clean water to a known mark, operate the sprayer for the time required to cover 1 acre (or run the distance equivalent to 1 acre on the road):

$$\text{Time to cover 1 acre (mins.)} = \frac{495}{\text{effective spray width (ft.)} \times \text{speed (m.p.h.)}}$$

$$\text{Distance to cover 1 acre (yd.)} = \frac{4840 \times 3}{\text{effective spray width (ft.)}}$$

$$\begin{aligned}\text{Effective spray width} &= \text{(dist. between first and last nozzle)} \\ &\quad + \text{(dist. between 1st and 2nd nozzle)} \\ \text{or} &= \text{(dist. between 1st and 2nd nozzle)} \\ &\quad \times \text{(no. of nozzles)}\end{aligned}$$

Then refill the tank to the same mark, measuring the amount of water required.

Alternatively application rate can be checked (" calibration " of sprayer) using formula:

$$\text{Application rate (gal./acre)} = \frac{\text{Delivery (lb. min.) of one nozzle} \times \text{no. nozzles} \times \text{time to cover 1 acre (mins.)}}{10}$$

Check boom height so that spray patterns from individual nozzles converge at the top of the foliage. Particularly with wide booms accurate " joining " of bouts is difficult. A weight towed from the boom tip helps in cereals, or alternatively a light marker to extend beyond the boom to the previous tractor wheel mark can be used.

Toxic Chemicals and Legal Requirements—Under the Agriculture (Poisonous Substances) Regulations, 1954 (S.I. 1954 No. 828) and subsequent amendments, both employer and operators must comply with certain requirements when applying DNC, Dinoseb, Parathion, Schradan, Sulfotepp, TEPP, Mipafox, Demeton, Dimefox, Mazidox, Amiton and arsenical compounds.

The requirements cover—the use of protective clothing, hours of work, keeping of records in connection with these chemicals, washing of sprayers, workers, and protective clothing, notification to the Ministry Inspectors of workers' absence or suspected cases of poisoning. Form A (PS)/1 "Precautions in the use of weed-killers and insecticides containing dinitro and organo-phosphorus compounds," published by the Ministry of Agriculture, includes recommendations as well as the Regulations.

Perhaps the most important factor in machine life is thorough cleaning *immediately* after use each day and before storage. Each night the machine should be emptied, filled with clean water and this sprayed out on waste ground where there is no danger from residues, and finally it should be refilled with water and left filled overnight to prevent caking of chemicals.

Particular care is necessary when changing from herbicide to insecticide. A wash (including the roof of the tank) with a solution of synthetic detergent is recommended followed by two plain water washes.

When laying the machine up after the spray season proprietary de-watering solutions are valuable as a final treatment. The outside of the sprayer should be thoroughly washed too, and care taken to drain pumps, etc., to avoid frost damage. Rubber parts should be removed and stored in a cool dark place.

Dusting is used for certain small jobs, such as protecting brassicas against flea bettle attack. They are not favoured for large-scale work unless some special consideration (such as lack of water) or the treatment of water repellent foliage (such as onions) is involved. Dusting is less efficient than spraying in its use of chemicals, the former generally requiring about twice the amount of toxic material per acre.

GRASSLAND MACHINERY

MOWERS AND GRASS CUTTERS

There are three main groups; cutter bar mowers, cylinder mowers, and rotary grass cutters employing blades attached to a central disc or boss which rotates at a high speed in a horizontal plane.

Cutter bar mowers cut without chopping and leave the crop lying in a neat swath upon the ground to be handled

subsequently by conventional hay- or silage-making machinery.

Cylinder mowers and rotary grass cutters are used when the cut material is not to be conserved (e.g., when pasture-topping or orchard grass cutting). They chop the grass and spread it fairly evenly on the ground. Cylinder mowers are more suitable for relatively short growth (say, up to 6 to 9 in. in height) whereas grass cutters cut long grass or weeds.

CUTTER BAR MOWERS

Types—Trailed models (for horse- or tractor-draught), rear-mounted, semi-mounted or mid-mounted models are available. Trailed models are wheel driven, the other types usually being driven from the tractor power take-off. Most have a hand-operated lift for the cutter bar, but mechanical or hydraulic lifts are obtainable on some makes. The following widths of cut are usual:

One-horse trailed mower	3½ ft.
One-horse trailed mower with engine-driven (2½ h.p.) cutter bar ...	4½ ft.
Two-horse trailed mower	4½ ft.
Tractor mower	5, 6 or 7 ft.

Five-foot-cut tractor mowers are commonly used, and many hay-making or forage-harvesting machines have been designed to follow mowers with this width of cut. British cutter bars usually have a finger spacing of 3 in., but a 2 in. spacing is common on the Continent and a 1½ in. spacing is sometimes used in the U.S.A. Accessories for mowers include harvesting attachments, swath boards for attachment to the inner end of the cutter bar to obtain a more compact swath, cutter bars for special duties (e.g., thistle bars).

Rate of Work—Tractor mowers usually travel at a forward speed of 2½ to 3½ m.p.h. (giving a rate of work of about 1 acre per hour); horse-drawn mowers travel at somewhat slower speeds.

Operation, Setting and Maintenance—To obtain satisfactory cutting, the knife sections must be reasonably undamaged and sharp; the points of the fingers undamaged; and the points and also the ledger plates of the fingers must

be parallel and in line with one another. The knife must be seating properly on the knife back and the knife sections should be parallel to and sufficiently close to the ledger plates. The clips (keeps) must be sufficiently tight; and the "register" of the knife with the fingers must be correct. The cutter bar lead should be $\frac{1}{4}$ in. per foot of cut.

Breakdowns are likely to occur if cutter bar mowers are driven at speeds higher than those quoted above. Moreover, although almost all mowers are fitted with some form of safety device to protect them against damage if the cutter bar strikes an obstacle or suddenly becomes jammed, the tractor must be stopped in a very short distance to avoid damage to the mower; and this cannot be done if the speed is too high.

Before storage, the cutter bar should be greased or covered with a rust preventive, and the machine should be thoroughly lubricated. The knives should be greased and stored in a dry place.

Cylinder mowers—Usually tractor-drawn, three mower units forming a gang with a width of cut of about 6 ft. They are normally tractor-drawn at speeds of 4 to 5 m.p.h. (sometimes slightly faster) and have therefore a higher rate of work than cutter bar mowers. Their cutting blades are more easily damaged than the other types, and they are not very suitable for use on stony land, unless the stones have previously been rolled well into the ground. Under such conditions maintenance costs can be high. The machines leave a neater, and often shorter, stubble than the other types when operating correctly.

For satisfactory cutting the blades must be true and the cylinder bearings in good condition; and the clearance between the cylinder and the bottom blade must be correctly set. Lubrication must be carried out at the correct intervals.

Preparation for storage includes thorough cleaning, lubrication and covering with rust preventive.

Rotary Grass Cutters—Sizes range from large, multiple-cutter-head, tractor-drawn machines with a cutting width of about $7\frac{1}{2}$ ft., to small, single-cutter-head hand-propelled machines with a cut of about 18 in. Most types employ a cutter-head which consists of a horizontal rotating disc with blades (usually 4) mounted at regular intervals on the

periphery. The blades are often similar in shape to cutter bar mower knife sections, but are specially ground so that they are all of the same weight. Mower knife sections cannot normally be used.

The stubble left by the machines is usually slightly longer and often slightly less neat than either of the other types. The rate of work of tractor-drawn machines is higher, often being in the region of two acres per hour. Moreover, being power take-off driven, they can be drawn at a wide range of forward speeds. In general they will tackle tough growth more satisfactorily than the other types of grass cutting machinery. Special types will cut brush and other woody undergrowth.

GREEN CROP LOADERS

These are now largely superseded by other types of silage-making machinery but, where the distances between field and silo are too great for buckrakes and conditions do not justify the cost of a forage harvester, are useful.

Types—Most are drawn behind a trailer and deliver the crop forwards, but types that are attached in front or to the side of a trailer are available. Both engine- and land-wheel-driven machines are made, the engine-driven machines usually performing more satisfactorily under difficult conditions because the forward speed can be varied without a corresponding alteration in the conveyor speed.

Two types of elevating mechanism are employed, either (*a*) the reciprocating fork type, which will usually also handle hay, but often is not so suitable for short crops, or (*b*) the endless conveyor type (e.g., slatted-chain or rubberised canvas conveyor).

Labour Requirement and Rate of Work—In addition to a tractor driver, one or two men are required on the trailer, depending on its size. The rate of work (usually between 2 and 4 tons/hour) is determined by the rate at which the men can handle the crop.

BUCKRAKES

These are normally rear-mounted on a tractor hydraulic lift linkage, but front-mounted models on various makes of tractor hydraulic loader are also available.

They are normally used when the distance between silo and field is relatively short (under about 500 yd.) and under such conditions the rate of work in terms of tons per man-hour can be high. Normally the minimum labour force is two, provided that the tractor can be driven on to the pit or silo to deposit the buckrake load, the second man levelling the loads on the silo and applying additives to the crop, if required.

The load weight varies between 5–10 cwt., depending upon the type of crop and the size of buckrake and tractor used.

The buckrake is best used when the crops are reasonably long (say 1 ft. to 1½ ft. high) and where the ground surface is fairly firm and even, if undue crop losses, contamination of the crops by dirt, and digging-in of the tines are to be prevented.

CUTTER BLOWERS

These are not commonly used, being employed for filling tower or other types of silo which cannot be conveniently filled by other means and where it is desired to chop the material before ensiling it. Most blow the crop to a height of about 50 ft., but the height varies from model to model.

They consist essentially of a feed mechanism which delivers the crop to a chopping and conveying mechanism (usually combined in one unit) which in turn delivers the chopped material through ducting to the silo.

Normally a tractor power of at least 30 to 35 h.p., and a labour force of two (sometimes three) men are required to obtain the maximum throughput. Under such conditions rates of work of between 5 and 10 tons per hour can be obtained.

FORAGE HARVESTERS

Those that chop or lacerate the crop are most popular, because the chopped material is usually relatively easy to handle and ensile. Although self-propelled machines are manufactured both in this country and overseas, the popular types are trailed and are usually power take-off-driven.

There are three main types: machines that cut and load the crop; those that cut, chop and load the crop; and

machines that pick up from a windrow, chop and load the crop.

The last two types are commonly used, some being adaptable to carry out either operation. There are four main types of cutting mechanism.

(*a*) conventional cylinder-type grass mowers, from which the crop is conveyed pneumatically through ducting to a trailer. Such mechanisms are only suitable for harvesting short crops;

(*b*) conventional cutter bars, from which the crop is conveyed pneumatically or by an elevator to a trailer (often through a chopping or lacerating mechanism usually of a modified cutter-blower type). Some machines can be fitted with a pick-up attachment;

(*c*) flail-type cutting mechanisms which cut and lacerate the crop and impell the cut material through ducting to the trailer. Such machines can be used either to cut a standing crop or to pick up from a swath or windrow.

Machines that do not cut the crop, but pick up the crop from a swath, chop it, and convey it to a trailer employ either a cylinder-type or fan (or impeller)-type cutting mechanism.

Labour Requirement—A considerable labour force is usually required if the maximum output is to be obtained. Where the trailer is drawn behind one of the smaller types of harvester the minimum labour force is usually four men: one man operating the outfit in the field, one man transporting trailers to and from the field, two men unloading trailers at the silo, with some assistance from the man transporting the trailers if the transport distance is relatively short.

Additional men are required if the distances involved are relatively long, the conditions such that considerable hand work is involved in unloading, or if the trailer is drawn alongside the machine by a second tractor.

Rate of Work—When using medium-powered tractors (35 to 40 h.p.) to drive a machine, the potential output is usually between 5 and 10 tons per hour depending upon field conditions, and assuming an efficient system is used so that there are few delays.

Operation—A well-organised transport and unloading system is essential if the potential output of the harvester is

to be obtained. It is essential that the gang unloading at the silo should be sufficiently large to unload at least as fast as the machine can fill the trailers. Standard trailers usually have not sufficient capacity and the trailer sides must therefore be extended. Such extensions should be easily detachable for unloading. At least two such trailers are required, but an additional trailer may be necessary if the transport time is considerable (say over ¼ hour). Two methods of unloading are commonly employed.

1. The trailer is drawn over a clamp or pit and the load either thrown off by hand, or pulled off by means of ropes laid in the bottom of the trailer prior to loading. Wheeled tractors usually prove incapable of pulling heavily-loaded four-wheeled trailers across relatively uncompacted silage, and a crawler tractor or winch usually has to be used under such circumstances.

2. The trailer is drawn alongside the silo and the crop is either thrown or elevated into the silo. More hand labour is required when using this method, but it avoids the danger of tractors or trailers becoming " bogged-down " in the silo.

When working a power take-off-driven machine on relatively steeply sloping land (over about 1 in 10) it is often advisable to employ a second tractor to draw the trailer, because otherwise an unduly high proportion of the available power is employed in towing the trailer rather than in driving the harvester, and the rate of work therefore falls considerably.

Where the land is stony, the need to sharpen or replace knives or cutters, and wear and tear in general, is greatly reduced if the land is rolled when moist in early spring to push any large stones down into the ground. It is also advisable to inspect the field at this time (particularly alongside the hedges) and remove any obstructions or rubbish that may damage the machine.

HAY-MAKING MACHINERY

Hay-making machinery falls into three categories:— 1. Swath hay-making. 2. Removing hay from the swath. 3. Equipment for weatherproof hay-making.

Swath Hay-making—Tedders should handle 2 five-foot swaths, and when used in heavy green crops should be driven

by the tractor p.t.o. The modern tedder has spring tines with an easily adjustable angle to vary the severity of treatment, and to alter the amount of aeration given to the crop, by "fluffing" it up. Conventional rake bar and spider head turners and side rakes merely turn the crop or move it sideways into windrows, and so ground wheel drive is satisfactory. Finger wheel rakes are driven by contact with the crop and ground, have few moving parts to wear, and will windrow at high speeds.

Working Rates—	Acres/hr.
P.t.o. driven tedder	3–4
Turners and side rakes	3–5
Finger wheel rakes	5–7

Close attention to tightness of tine fixings and to grease points is essential in all types for satisfactory work and long life.

Crushers and lacerators which split the sappy parts of the plant may be used to speed up drying, but the severity of the action can cause leaf loss, and output is low at 1 to 2 acres per hour. Aerators, which deal with the crop very gently, may be used in valuable seed crops, or to keep leaf loss to a minimum.

Hay Balers—Pick-up balers are of two basic types:—
1. High or medium density slicing ram, tying with string or wire. 2. Low density swinging ram baler or trusser, string tying.

High or medium density balers are best suited for use in well-dried hay of 25 per cent. moisture content or less, and produce a tightly packed neat bale. Density of bales should be related to the "greenness" of the hay at baling as indicated.

Moisture content per cent.	Maximum density lb./cu. ft.
30	9
25	12
20	15

Operation at correct number of ram strokes per minute is important, and varies with make between 50 and 70. Knotters must be kept free of excess dirt, should be properly

greased, correctly tensioned, and the string knife must be sharp.

Output...	5 to 10 tons per hour
Average bale size	36 in. × 18 in. × 14 in.
,, ,, weight	50 to 60 lb.
Twine type	205 ft./lb.
Average weight twine per ton	4 to 4½ lb.

Low density balers pack the bale much more loosely at 4 to 7 lb./cu. ft. Hay at up to 35 per cent. moisture can be safely baled if stored in a well-ventilated place. The ram operates at 48 to 55 strokes per minute.

Output...	5 to 7 tons per hour
Average bale size	39 in. × 12 in. × 16 in.
,, ,, weight	20 to 40 lb.
Twine type	400–500 ft./lb.
Average weight twine per ton	1½–2 lbs.

Equipment for Weatherproof Hay-making—For high quality hay three basic types of equipment are available, details of which are given in the following Table:

TABLE 72: WEATHERPROOF HAY-MAKING EQUIPMENT

	Hut Racks	Tripods	Tetrapods
Loading moisture content, per cent.	50–65	40–60	35–50
Swath wilting, hrs.			
Fine weather	6–8	8–40	24–48
Dull ,, ...	8–40	24–72	24–72
Drying rate, days	4–21	7–28	7–28
Weight hay per frame, cwt. ...	3–4	2½–3	3–4
Length of timber per frame, ft.	96	21	56
Cost of materials	12s. to 18s.	2s. to 3s. 6d.	6s. to 9s. 6d.
Nett labour requirement, man hrs. per ton			
Hand loaded	1½–2½	2½–5	1½–4
Machine loaded	1½–2¼	1½–2	1½–2

Barn Hay-drying—Data of equipment required to dry hay loose or in bale by different methods, with or without supplemental heat, is given overleaf.

TABLE 73: BARN HAY-DRYING EQUIPMENT

	Cold air—storage	Medium air speed—batch	Cold blow/hot blow or Highlow
Airflow, f.p.m.—loose	20–25	25	60 and 20
—baled	25–30	35	60 and 20
Temperature rise used °F. ...	Nil	10–12	15–25
Moisture content per cent. at loading	35–40	35–50	45–60
Loading depth—			
Loose—Initial, ft.	10	8–10	5–8
—Final ,, ...	18–25	15	—
Baled—Initial, bales ...	6	4–6	3–5
—Final ,, ...	12	9	—
Drying time	3-4 weeks	10–14 days	3–5 days
Seasonal output per 350 sq. ft. floor	10–15 tons	15–25 tons	30–40 tons
Running cost per ton	10s. to £1	10s. to £2 10s.	£2 to £5
Capital cost per 350 sq. ft. floor	£200	£250	£500

Drier capacity—Loose hay 400–500 cu. ft./ton
Baled ,, 250–350 cu. ft./ton
Labour—cutting to loading (incl.) 7 man hrs./ton
For heated air 3·165 kW raises 1000 c.f.m. 10° F.
1 kWh = 3412 B.Th.U.

HARVESTING MACHINERY

BINDERS

Although the modern trend is to harvest corn crops with combine-harvesters, the binder method is still the more economical on many British farms. Apart from producing long, unbroken straw, frequently required for covering clamps and thatching, the binder helps to even out the labour demand.

The main components of a binder are: (i) the frame, usually of tubular construction, (ii) the cutting and gathering mechanisms, (iii) the elevating system, consisting of three endless canvasses provided with wooden slats, and (iv) the binding mechanism.

In the older and heavier machines, power for driving the cutting and binding mechanisms is obtained from a large, cleated bull wheel. However, p.t.o. drive is now almost universal; it permits cutting widths of up to 10 ft. to be employed and is particularly useful where harvesting conditions are difficult. Semi-mounted binders, which have

been introduced in recent years, have the advantages of lightness, manoeuvrability, and lower initial cost.

The cutting mechanism of the binder differs from that of the mower in two respects; the speed of the knife is lower, and the throw of the crank is 6 in. instead of 3 in. Thus, the knife sections register only with every other finger on the cutter bar.

Adjustments needing constant attention in varying crops are:—1. Reel height and pitch. 2. Pitch of platform. 3. Position of band round sheaves.

Twine tension, which is most important for faultless tying, may be checked with an ordinary spring balance at the twine retainer and at the end of the needle, the correct tension being 35–40 lb. and 8–10 lb. respectively. Twine consumption is normally 3–4 lb./acre at a runnage of 550 to 650 ft./lb. of twine.

When windrowing with a binder, care should be taken that the hitch is so adjusted that the cut crop falls on undisturbed stubble.

Binder attachments include sheaf carriers, mounted and trailed; pick-up reels; crop lifters and special dividers for laid crops.

COMBINE-HARVESTERS

An acreage of 22 per foot of cutter-bar width is commonly quoted as an average of what a combine-harvester can do in a season. This may vary, however, according to the district, the weather and the available drying facilities from 15 to 30 acres per foot.

The two main types of combine are the trailed and self-propelled machines. The latter have the advantages of (*a*) better visibility and control by the operator, (*b*) greater flexibility and manoeuvrability, and (*c*) lower grain losses when opening up fields. The first cost, however, is considerably greater.

Widths of cut normally range from 3 ft. 6 in. to 7 ft. in trailer type combines, and from 6 ft. to 16 ft. in self-propelled models. When combining grain crops, five basic operations are performed: (i) cutting (or picking up from the windrow), (ii) conveying and feeding the cut material to the threshing mechanism, (iii) threshing, (iv) separating seed and chaff

from the straw, (v) cleaning or dressing the seed. Grain losses may occur in connection with any of these operations. One wheat or barley grain lost per sq. ft. is approximately equal to a loss of 4·2 lb. per acre, and one oat grain per sq. ft. is equal to about 3·5 lb. per acre. Excessive damage and/or losses are likely to result if an incorrect drum speed or concave clearance is used. Correct settings for a variety of crops are tabulated below.

TABLE 74 : CORRECT ADJUSTMENTS FOR COMBINE-HARVESTER

Crop	Peripheral speed ft./min.*	Concave clearance† in.
Barley	4500–5500	$\frac{1}{4}$–$\frac{1}{2}$
Beans, edible	1500–2500	$\frac{5}{16}$–$\frac{3}{4}$
Beans, seed	1000–1500	$\frac{5}{16}$–$\frac{3}{4}$
Clovers	5500–6500	$\frac{1}{16}$–$\frac{5}{32}$
Flax	5000–6000	$\frac{1}{16}$–$\frac{1}{4}$
Lucerne	4000–6000	$\frac{1}{16}$–$\frac{5}{16}$
Oats	5000–6000	$\frac{3}{16}$–$\frac{1}{2}$
Peas	2000–3000	$\frac{5}{16}$–$\frac{3}{4}$
Rice	4000–5000	$\frac{3}{16}$–$\frac{3}{8}$
Rye	5000–6000	$\frac{3}{16}$–$\frac{1}{2}$
Sorghum	4000–5000	$\frac{1}{4}$–$\frac{5}{8}$
Soya beans	2500–3500	$\frac{5}{16}$–$\frac{7}{8}$
Wheat	5000–6000	$\frac{3}{16}$–$\frac{3}{8}$

* In quoting peripheral speed the effect of differing drum diameters is eliminated.

$$\text{R.P.M.} = \frac{\text{peripheral speed (ft./min.)}}{\text{drum diameter (ft.)} \times 3{\cdot}142} \text{ or}$$

$$= \frac{\text{peripheral speed (ft./min.)} \times 7}{\text{drum diameter (ft.)} \times 22}$$

† Applicable to rasp-bar drums only.

When operating trailer-type combines which are p.t.o. driven, the engine speed of the tractor must be kept constant. To enable the tractor to be stopped and restarted without having to stop the threshing mechanism of the combine, a "live" or continuous running p.t.o. is desirable. Trailed combines fitted with auxiliary engines are more flexible, though somewhat more expensive than p.t.o. driven models. The rate of work which may be expected under average

conditions from a small p.t.o. driven machine requiring a 20–24 h.p. tractor is approximately 0·5 acres/hr. Self-propelled machines powered by 60–65 h.p. engines are capable of harvesting approximately 1·4–1·8 acres/hr.

Mechanical tests have shown the power requirement of 5–6 ft. cut p.t.o. driven combine-harvesters to be 2 to 4·5 h.p. per foot of cut, while 2 to 3 net h.p. per foot of cut are commonly allowed for 8–12 ft. cut self-propelled machines.

In the U.S.A. special hillside combines have been developed in which the threshing mechanism is kept level independent of the slope of the field by means of automatically controlled hydraulic rams. One model gives side as well as fore-and-aft levelling.

Of the many attachments available for combine-harvesters the most important are:—Windrow pick-ups, pick-up reels, grain lifters and guards, special dividers, straw bunchers and windrowers, straw choppers and spreaders, and low-density presses.

Special ancillary equipment is provided for the harvesting of such crops as beans, clover, flax, lucerne, timothy, and vetches.

ROOT CROP MACHINERY

POTATOES

Potato Lifters—The following machines may be used for lifting potatoes:—1. Plough. 2. Spinner. 3. Digger (single or two row). 4. Harvester.

The plough is the simplest implement for lifting potatoes, works under adverse conditions, does little damage to the tubers but the potatoes are not well exposed, which makes picking difficult. The spinner, the most widely used implement for this work, functions in wet conditions and in the presence of haulm, and if correctly adjusted leaves the potatoes on the surface, but scatters them in a band up to 5 ft. wide. The digger, on the other hand, leaves the potatoes in a narrow band and the saving in labour resulting from the more rapid picking generally justifies the use of the more expensive machine. The use of a two-row digger leaves the potatoes in a narrow concentrated band which allows for a further increase in picking rate, gives a more economical use of the tractor, and makes "continuous digging" possible; the

digger and pickers can then work independently, thus reducing delays. Potato harvesters aim to produce a clean sample of potatoes in one operation. Normally about four pickers are carried and usually have semi-automatic clod and stone separators incorporated. They tend to be complicated, expensive machines, susceptible to changes in soil conditions but when a daily output of not less than 2 acres can be maintained a saving over the older methods is apparent.

In the adjustment of all potato harvesting machinery a compromise must be reached between cleaning and damage prevention. Damage to the tubers can be reduced in a digger by a relatively high forward speed, a low web speed, and the removal of agitators. The object should always be to adjust the machine to allow a cushion of soil with the potatoes until just leaving the digger. Particular care should be taken to avoid damage in potato harvesters by suitable adjustment and by placing straw bales in the bottom of trailers to prevent the potatoes from being damaged on falling from the final delivery elevator.

Normally the rate of working is dependent on the number of pickers employed. One picker working behind a single-row digger should pick about 2 tons per day, under ideal conditions 3 tons are possible. Shallow baskets are normally found the most suitable receptacle to pick into. Emptying these directly into a trailer requires careful organisation, but is more efficient than emptying into sacks. The use of stillages or boxes of 5 cwt. capacity which can be raised and emptied into a trailer with a tractor front-end loader is a considerable labour saver.

Potatoes may be stored in buildings without ventilation to a depth of 6 ft. or 12 ft. with ventilation; for the latter depth a 20 ft. elevator would be required.

SUGAR BEET

Lifters are commonly of the multi-row toolbar-mounted type and are followed by men who pull, knock and top the beet. Two main types of lifter are used: the bow-type with share working on each side of the row and the single-leg type which runs alongside the roots and for which a variety of share designs are made. Multi-row lifters damage the rows if they are not straight, parallel and uniform in width.

The number of rows in the lifter should be the same as or a simple fraction of the number of coulters in the drill.

Lifter-cleaners consist of a share, or shares for some lift two rows at a time, which delivers the roots into the cleaning unit. The latter may be a land-driven cleaning drum or a power take-off-driven horizontal spinner. In districts which produce small tops the horizontal spinner type of machine is frequently used to lift and clean the beet and leave them in windrows ready for hand topping and loading. If topped mechanically while the roots are still in the ground the tops must be moved to one side before the lifter can operate.

A complete harvester tops, lifts and cleans the beet before discharging them. In addition, many machines gather the tops into heaps for easy collection. To reduce the overall length of the machine many designers have fitted the topper unit to the side of the machine; the topper then works one or two rows in advance of the lifter shares. Some machines top the beet after lifting and may be more suitable for stony soils.

The efficiency of modern harvesters is such that the quality of work is, under most conditions, comparable with hand-work while a rate of working of 0·25 acres per hour is possible.

Most designs of topper unit have provision for adjusting the vertical distance between the feeler and cutting knife and many allow the knife to be moved forwards or backwards also, which adjustments are used to produce the desired standard of work. A survey carried out in 1949 showed that the dirt tare and top tare were 12·3 lb./cwt. and 3·0 lb./cwt. from machine harvested beet compared with 12·2 lb./cwt. and 2·5 lb./cwt. from all the crops within the area.

Considerable loss of sugar is likely to result if topped beet are left in the ground before being lifted, a fall in sugar of 0·15 per cent. per day during the first week being recorded.

Mechanical harvesters knock the soil from the roots while it is still damp and care is necessary if undue damage to the roots is to be avoided.

The loading of the roots into road vehicles is often done by mechanical elevators or fore-end loaders. Considerable care and skill is required if an undue amount of soil is not to be lifted with the fore-end loader. This trouble can be avoided by loading from a smooth level surface (concrete) and it is possible that by using the fore-end loader to deliver into a suitable elevator marked cleaning of the roots will result.

THRESHING MACHINES

Threshing Machines consist primarily of a cylinder and concave in which the grain is threshed, straw walkers to remove the straw from the drum and a series of fans and sieves to clean and grade the grain. Ancillary equipment consists of a self-feeder and automatic band cutter, blowers to remove chaff and convey the grain to a point of storage, and a trusser chopper and/or blower to handle the straw.

A machine fully equipped in this way can be handled by 3–4 men as opposed to 10–12 men with a hand-operated thresher.

The threshing cylinder is either of the rasp-bar or peg-drum type, the former being by far the more common. It is usually 24 in. in diameter and either 48, 54 or 60 in. in width and such a machine requires 6–10 horse power. Determined to some extent by the width of the cylinder the output is 20–25 cwt. per hour of wheat with an increase of $\frac{1}{3}$ to $\frac{1}{2}$ for oats and barley.

The peg drum is usually associated with the smaller machines and normally has a cylinder 22 in. in diameter and 36 in. in width. For successful operation some 50 per cent. more horse power is required although the output may be increased by as much as 5 cwt. per hour.

The thresher should be level on the ground and the feed to the drum maintained at a uniform rate, a requirement helped considerably by the use of a self-feeder. Moreover, the whole machine should be operated at the correct speed which in the majority of cases is of the following order:

Drum	revs per min.	1000–1200
Shakers	,, ,, ...	180
Riddles	,, ,, ...	180
Fan	,, ,, ...	700
Elevator	,, ,, ...	100
Screen	,, ,, ...	25

If the cylinder is operated at its correct speed, then the straw walkers, sieves and elevators and other moving parts fall in line, being driven from the drum shaft.

To obtain a satisfactory standard of threshing and avoid damage to the grain the cylinder should be rotated at the speed recommended and the concave so set that the distance

between the outer surface of the beater bar and the edge of the concave is $\frac{3}{4}$ in. at the top, $\frac{1}{2}$ in. at the centre, and $\frac{1}{4}$ in. at the bottom. These distances must be reduced if the grain is small and the optimum setting can only be obtained by trial and error. Generally, however, if the grain is being cracked then the concave setting is too close, and the cylinder speeded up if the ears are coming over the back unthreshed. Under all conditions the rule should be to use only the widest concave setting and the slowest cylinder speed that will give the desired standard of threshing.

For efficient cleaning and grading the riddles, sieves and fan settings should be those recommended by the manufacturer for the crop in hand.

Threshing Grass Seeds—All grass seeds with the exception of Timothy can be threshed with a standard machine provided a metal shield is fixed to the top of the concave to prevent loss of heads and the clearance between cylinder and concave is adjusted to around $\frac{5}{8}$ in. at the top, $\frac{1}{2}$ in. at the centre and $\frac{3}{8}$ in. at the bottom. For ryegrass the cylinder speed should be reduced to around 1100 revs. per min. but for cocksfoot a speed of between 1200 and 1250 may be necessary for the best results. Losses of seed can be prevented by blanking off the first two or three sections of the cavings riddle and by reducing the blast from the first fan. The rotary screens should be closed so that the best seed falls through the end normally associated with the tail corn. The unthreshed material then falls through the top corn opening and should, of course, be put through a second time. For grass seeds hand feeding is preferable to the use of a self-feeder and the heads should be held close to the cylinder for a short time before allowing to enter the drum. Feeding should be rather slower than is the case with cereal crops. An output of 4 cwt. per hour from a 54 in. drum is reasonable.

Although numerous attachments can be obtained the sole aim in a standard threshing machine, with clover, should be to remove the seed heads from the straw, the threshing out of the actual seed being far better carried out in a properly designed clover huller.

BARN MACHINERY

Hammer Mills—There are broadly two groups, large and medium powered mills, having a capacity 5–40 cwt./hr.,

and the small automatic (electric) mills of 1–5 h.p. A 3 h.p. automatic mill may only grind 1¼ cwt./hr. of barley through a 1/16 in. screen, but produce 8 cwt./hr. through a ¼ in. screen. They are currently being produced fitted in combined milling and mixing units, the latter section of the outfit being started when grinding into the hopper of the mixer is complete.

For tractor driven mills use a belt of 4-ply, 5–6 in. wide.

Note that damp meal deteriorates more rapidly than grain at a corresponding moisture content.

STORAGE CAPACITIES FOR MEAL

(cu. ft./ton)

	Wheat	Oats	Barley	Beans
Meal	76	85	70	66
Whole grain ...	46	70	51	43

The peripheral speed of the hammers is generally in the region of 13,000–15,000 ft./min. Screen sizes range 1/32–¼ in. round holes. As examples: ⅛ in. screen grinding barley for pigs, ¼ in. screen for oats for cows.

Plate and Roller Mills—Roller mills are suitable for automatic operation in the same way as hammer mills but plate mills are not. Plate mills are particularly adapted to coarse grinding or kibbling. Roller mills for rolling cereals for cows or horses. The power consumed by a plate mill is similar to that for a hammer mill having the same output.

Food Mixers—Food mixers are available in sizes 5–30 cwt., the 10 cwt. vertical being the most popular. Auger speeds 40–340 r.p.m.

Rules for mixing:

1. Minor constituents (3 per cent. or less of total) should be pre-mixed by hand with a bushel of cereal meal or other free-flowing material.

2. Start with 2–3 sack of cereal meal (or other major constituent).

TABLE 75: RATES OF WORK, POWER AND DRAUGHT REQUIREMENTS OF VARIOUS MACHINES

	Rate of work* acres/hr.	Power to drive mechanism h.p.	Working width	Draught†
Plough, 2-furrow	½	—	20–30 in.	4–16 lb./sq. in. furrow section
Plough, 3-furrow	¾	—	30–45 in.	4–16 lb./sq. in. furrow section
Cultivator	1–1½	—	6–10 ft.	90–200 lb./ft.*
Disc harrow	1–1½	—	6–10 ft.	80–200 lb./ft.
Roll	5	—	8–24 ft.	25–60 lb./ft.
Spike-tooth harrow	6	—	15–21 ft.	40–80 lb./ft.
Drill	1½	—	7½–14 ft.	40–90 lb./ft.
Fertiliser distributor	1½	—	6–17 ft.	10–35 lb./ft.
Muck spreader	—	5	6–15 ft.	—
Mower	1	⅛/ft. cut	4½–7 ft.	60–100 lb./ft.
Swath turner	4–5	—	—	—
Hay sweep	1	—	8–10 ft.	—
Pick-up baler	2–3	10–25	—	400–800 lb. total
Forage harvester	1–2	20–30	—	—
Binder	1½	4–7	5–8 ft.	60–150 lb./ft.
Combine-harvester (trailed) ...	½–1	2–4½/ft. cut	5–7 ft.	—
Combine-harvester s.p.	1¾	3–5/ft. cut	6–12 ft.	—
Potato planter 3-row manual ...	½	—	56–84 in.	700–1000 lb./row
Potato spinner	½	2½–3½	—	1000 lb./row
Potato digger	⅓	3–4	—	1000 lb./row
Potato harvester	¼	5–10	—	—
Sugar beet harvester	¼	4–8	—	—
Sprayer	4–7	1–5	15–40 ft.	—
Thresher (on wheat)	1½–2 tons/hr.	0·8–1·2 h.p/in. of drum	—	—
Hammer mill (fine grind) ...	0·5 cwt./h.p. hr.	¾–40	—	—
Cutter blower	5 tons/hr.	25–35	—	—
Food mixer	1–2 tons/hr.	3–5	—	—

* This represents the overall rate of work, that is with a reasonable allowance for stops.
† Unless otherwise stated the draught is quoted as pounds per foot of working width.

3. Add the minor constituents (pre-mixed where necessary) and then remainder of cereals, etc.

4. Mixing time after last constituent is added = 10–15 min. (less, i.e., 3–5 min. for horizontal mixers).

5. For really good results return first two bagfuls to the mixer.

Hand mixing is approximately as good as thrice hand-shovel mixing.

CONTRACTING CHARGES

Selection of recommended prices for general agricultural contracting work as issued to members of the National Association of Agricultural Contractors in 1957 (all prices "per acre" unless otherwise stated):—

Ploughing arable and grassland	40s 6d. to 64s. 6d.
" deep (over 10 in.)	86s. to 136s.
Cultivating, standard	20s.
" heavy...	26s. then 20s.
Harrowing, disc standard	20s. then 15s.
" " heavy	25s. then 20s.
" spring-tine	13s.
" plain	10s.
Rolling, flat or ring, set of 3	7s. 6d. to 14s.
Drilling, corn (excluding man on drill)	20s. to 26s.
" combine " " " " ...	26s. to 36s.
Fertiliser distributing	15s. (up to 3 cwt. + 1s. per cwt. over)
Grass mowing	21s 6d. to 26s.
Cutting corn and binding (excluding second man and twine)	27s.
Combining (including two operators)	86s. to 97s.
Baling (hay or straw stationary, one man, no wire or string)	29s. 6d.
Pick-up baling hay or straw (including twine)...	8d. to 1s. per bale
Muck loader and tractor	29s. 6d per hour
Tractor and spreader (wheel drive)	26s. 6d. per hour
Potato ridging	20s. 6d. to 28s. 6d
Planting potatoes or cabbage (driver only) ...	34s. 6d. to 69s. 6d.
Potato spinning	23s.
Sugar beet lifting	40s.
" " complete harvester (no carting) ...	£10 upwards
Threshing (including 2 men, fuel, self-feeder and chaff and cavings blowers)	37s. 6d. per hour
Tractor hire (medium wheel + driver) ...	20s. per hour

FARM WORKSHOP

List of Equipment—Bench vice, 4½ in.; 2-lb. ball pane hammer; 2–3 cold chisels (various sizes); 2–3 punches

(various sizes, including centre punch); hacksaw and two grades of blade; range of files; 7-in. pliers (combination); vice grips; small pointed pliers; large, medium and small (electrical) screwdrivers; Whitworth spanner (double open-ended) up to 1 in.; U.N.F. (or S.A.E.) spanners up to $\frac{3}{4}$ in.; 12-in. and 6-in. adjustable spanners; breast drill from $\frac{1}{8}$ to $\frac{1}{2}$ (by 1/16ths); range of drip trays for oil changes, etc.; racks and shelves for tools and spares; tyre pump; wire brush; 2- to 3-ton hydraulic jack.

On larger farms add—Electric drill (pedestal or bench) for up to $\frac{3}{4}$ in. with suitable bits; electric drill, $\frac{1}{2}$ in. portable; electric bench or pedestal grinder; oxy-acetylene welding kit.

FORMULAE

Rates of Work and Speed—

Rate of work (acres/hr.) no allowance for lost time

$$= \frac{\text{width of swath (in.)} \times \text{speed (m.p.h.)}}{99}$$

or approximately, acres/hr. =

$$\left[\text{width (in.)} \times \text{speed (m.p.h.)}\right] \div 100.$$

Rate of work (acres/hr.) with 20% allowance for stops

$$= \frac{\text{width swath (ft.)} \times \text{speed (m.p.h.)}}{10}$$

(Note in the case of ploughing divide by 18 instead of 10 to allow for turns, marking out, etc.)

$$\text{Miles per acre} = \frac{99}{\text{swath width (in.)}}$$

$$\text{Yards per acre} = \frac{99 \times 1760}{\text{swath width (in.)}}$$

Row width (in.)	10	15	20	25	30
Row length (miles per acre)	9·9	6·6	4·9	4·0	3·3

88 ft. per minute $= 1$ m.p.h.

$$\text{Speed approx. m.p.h.} = \frac{\text{no. paces in 20 seconds}}{10}$$

Plant Population

Plant population per acre

$$= \frac{99 \times 5280 \times 12}{\text{row width (in.)} \times \text{space between plants (in.)}}$$

$$= \frac{6{,}272{,}640}{\text{row width (in.)} \times \text{space between plants (in.)}}$$

Water Pumps

Pump h.p. (net)

$$= \frac{\text{throughput (gal/hr.)} \times \text{lift (ft.)} \times 10}{60 \times 33{,}000}$$

To this must be added 60–80% for losses due to friction, leakage, etc.

Maximum suction lift of water, theoretical = 34 ft.
Maximum suction lift of water, practical = 25–28 ft.

If D = diameter of pump cylinder in inches.
L = length of pump stoke in inches.

Theoretical delivery of pump (g.p.m.) = $0{\cdot}034 \times$ no. cylinders $\times$ no. strokes/min. $\times L \times D^2$

Cubic inches per stroke $= 0{\cdot}785\ D^2L$
Gallons per stroke $= 0{\cdot}00283\ D^2L$
Cubic feet per stroke $= 0{\cdot}000454\ D^2L$
Pounds per stroke $= 0{\cdot}0283\ D^2L$

Deep wells:—

Gal. of water/hr....	200	350	500	650	800	1000
Height lift for 1 h.p. engine (ft.) ...	990	561	396	308	242	198

Wells

Best made with reinforced concrete rings of 3 ft. or more diameter, and each ring 2 ft. deep. Earth is excavated from the interior, and the bottom rings slip gradually down,

another ring being fitted on top as they sink. For straight work the four bottom rings ought to be bolted together with slips of quartering inside to prevent them from becoming displaced as they sink.

Siphons

Where a well is situated on high ground the water may be siphoned out by a pipe fixed over the edge of the well and down into the water. The long " arm " of the pipe will " suck " the water up over the bend to any height less than 30 ft. and deliver where required at a lower level.

FARM BUILDINGS

PRELIMINARY TASKS

A FARM building should be erected on an open, well-drained site, preferably with a south-easterly aspect. A slightly sloping site is an advantage simplifying and often reducing the cost of drainage, and in addition loading bays can be constructed from a single floor level. On exposed sites advantage should be taken of existing trees, or a spinney, to form wind breaks, even where additional planting is entailed.

The type of buildings forming the steading depends upon the system of farming. Keep all livestock and feeding stuffs to the south side of the farm, and Dutch barns, implement sheds and fertiliser stores to the north of these.

The U.E. or T-shaped layouts favoured by our forefathers have much to commend them. The higher buildings such as barns, granaries and mixing houses are on the north side, open-fronted sheds run to the east and west of them, whilst the cowhouse and other livestock buildings run at right angles in one, two, or three ranges, on a N.–S. axis. This provides space for yards, or courts, which can be covered, or left open to the south and are protected by buildings on two or more sides.

Planning—Modern buildings should be planned to the last detail. When existing buildings form part of a scheme they should be surveyed, levels taken over the site, and water supplies and drains, where they exist, located, and the form and construction of the new work determined in relation to the old. The scheme as a whole should then be fully worked out on paper and the building designed to fit the circumstances. In this way capital outlay, building maintenance, duplication of machinery and wasted time and effort of farm workers are all considerably reduced. The majority of the problems facing Time-Study Engineers on farms, result from lack of careful planning. To put a plan into a building after it has been erected can be a complicated and costly business, even when carried out by a Time-Study Engineer.

When developing a new site it is advisable to group all the buildings, including farmhouse and cottages, as near to a public highway as possible. This reduces the cost of road making and consequent maintenance, water supplies, drainage, electricity and telephone services.

A tractor is the mobile power unit of a modern farm and must have good road layout if it is to be used efficiently. With a trailer it needs a 30 ft. diameter turning circle to get round a corner, or into a building. A five-ton lorry needs 45 ft. diameter turning circle.

CATTLE HOUSING

COWSHEDS

A properly constructed cowshed may cost less than an open yard and milking parlour, but is not so flexible, and is rather more wasteful of farm labour owing to the necessity for daily cleaning out. It is, however, ideal for exposed, wet localities, and for those farmers who prefer to manage their stock individually. Double range cowsheds should be sited along a north and south axis, where possible, to provide equal amounts of sunshine on both sides of the building, and to avoid having the main entrance door at the end facing the prevailing wind.

Condensation problems are a contemporary manifestation brought about by the use of unsuitable modern building materials (see building data) in combination with lack of ventilation.

A single range cowshed without a feeding passage should not be less than 14 ft. 6 in. wide, made up as follows: Standing and manger, 7 ft. 6 in.; dunging channel, 3 ft.; gangway, 4 ft. When a feeding passage is provided it should not be less than 3 ft. wide.

A double range cow-house is more economical of labour for herds of more than 16–20 cows and should not be less than 27 ft. wide without feeding passages. A feeding passage both sides adds a further 6 ft. to the width and approximately 18 per cent. to the floor area, increasing the cost of the building proportionately. The central gangway should be not less than 6 ft. wide.

Walls—Stone or brick are the most suitable materials for walls. Concrete blocks, hollow or solid, need vertical

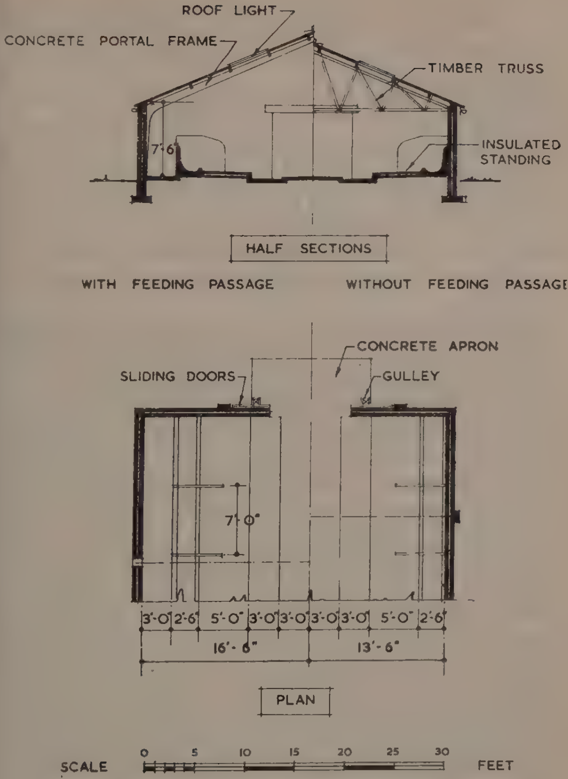

Fig. 26. Double range cowhouse.

expansion joints at approximately 12 ft. intervals if fractures are to be avoided. Concrete is a poor insulator and some kinds are very porous. An 11 in. cavity wall makes the most satisfactory type of insulated wall. Brick piers are preferably constructed on the outside walls. All external angles within a cowshed, including the jambs of the doors, should be constructed with bull-nosed bricks. Internal walls should be rendered to a height of 4 ft. 6 in. and the angle between wall and floor should be coved. Internal angles should also be coved to facilitate cleaning down.

The height of the wall should be about 7 ft. 6 in. from the feeding passage floor to the wall plate, although a great deal depends upon the type of roof truss used, in which case headroom is the limiting factor. Most cow-houses are made far too high.

Floors—Generally should be impervious—smooth enough to be easily cleaned but not liable to become slippery. Concrete, the usual material, should be laid on 4 in. consolidated hardcore. If there is a natural fall in the site along the length of the building, it is economical to allow the floor to fall with the ground, providing it is not too steep.

Standings—The cow standing should be impervious, and insulated, and should have a fall of 1½ in. from the front curb of the manger to the dunging channel. The surfaces of the standing should be roughened to provide a good foot-hold, 6 in. to 9 in. of the standing next to the dunging channel being left smooth. Hard engineering bricks laid flat in herring-bone pattern, or 18 in. × 18 in. roughened precast concrete slab infilling, may be used as an alternative to roughened concrete. The floor should be insulated with 4 in. " no-fines " concrete, or hollow clay blocks, laid on a horizontal damp-proof course comprising tarred paper, or bituminous felt, laid over 4 in. hardcore. On heavy wet soils the damp-proofing is more important than the insulation.

Dunging Channels—These should be 3 ft. wide, with a 6 in. minimum step-up to the standing, and a 2 in. step-up to the back walk or gangway. There should be an inch fall-away from the standing, and a longitudinal fall of half an inch per cow in the length of the dunging channel. It should have a smooth finish with internal coved angles. The narrower and deeper channel used on the Continent has

much to commend it and can be from 16 in. to 18 in. wide with a 6 in. minimum step-up to the gangway. Such channels are usually used in conjunction with mechanical gutter cleaners.

Mangers—Can be constructed of either precast concrete or *in situ* concrete, or alternatively glazed stoneware. It is advisable to line all concrete manger bottoms with glazed stoneware channels, particularly where silage is fed, as acids will eventually destroy the cement in the concrete. The channel should be one-third round, and 15 in. diameter. The width of a manger varies from 1 ft. 6 in. to 3 ft. depending upon the type, and the method of tying. With a yoke, or other central tie secured to the centre of the front curb of the manger, the greater width is necessary. The limiting factor with side ties, however, is the distance between the front of the manger and the wall, or head rail in the case of a feeding passage at the back. This should be not less than 2 ft. 6 in., irrespective of the width of the manger, otherwise a cow is forced to stand back with its hind legs in the gutter. A good deal of foodstuff is often wasted because mangers are too narrow, and 2 ft. 6 in. should be regarded as a minimum in any case.

The front curb of the manger should not be more than 6 in. in height above the standing, and the back of the manger 2 ft. 6 in. high above the level of the feeding passage. Mangers can be divided up into separate sections for each cow, to prevent them from taking each other's rations. Concrete divisions are expensive to construct and difficult to clean out. Lift-up steel divisions rust along the edges after a time and become sharp and dangerous. Wooden lift-up partitions are better but are often heavy to operate and also unhygienic. An alternative is to use removable feeding tubs of either wood or metal, in conjunction with a flat-bottomed manger. It is advisable to secure the tubs to prevent the cows from moving them about. The manger in this case should be lined with quarry floor tiles with coved tiles forming the internal angles.

Where separate standings are provided for each cow, some farmers prefer to dispense with a manger completely. Sweep-in mangers, having the feeding passage level with the back of the mangers, are extensively used on the

Continent, and have much to commend them; in which case, the feeding passage floor should be at the same level as the top of the manger and should stand about 10 in. above the level of the standing.

Hay racks at high level are not recommended in any farm building.

Stall Divisions—Can be of precast reinforced concrete, or tubular steel. Stalls for two cows should not be less than 7 ft. wide, whatever the breed. Udder troubles can often follow cows treading on each other's teats in too narrow standings, particularly in the case of the larger breeds. Single stalls should not be less than 4 ft. wide. The edge of the stall divisions should be set not less than 3 ft. away from the curb of the manger. Tubular divisions should be set on a raised concrete curb about 6 in. high above the standing, as it not only prevents the tubes from rusting at the bottom but confines the bedding to the standing and prevents injury to the cows. The Dutch use loose hairpin or bent U-shaped tubes let into insets in the standing, the removal of which they maintain facilitates periodic cleaning out of the cowhouse.

Ties—Cows may be secured by centrally fixed head yokes now seldom used since they restrict the movement of the cow. Side ties are better as they permit more freedom of movement and are more adjustable. The Dutch stretch a chain, which can be adjusted for tautness, between the ceiling and floor, slightly to one side of the cow standing. The cow is attached to this chain by means of a light aluminium alloy collar and a loose ring which runs up and down it. It undoubtedly provides more comfort for a cow than head chain or yoke.

Drainage—All drains within the cowhouse should be of the open channel type. Where channels cross traffic routes they should be covered over with movable cast iron, or light precast concrete slabs. Cross channels need not be wider than 12 in. and should discharge over external trapped gullies.

Liquid manure should be drained away to a liquid manure tank, conveniently situated for emptying and large enough to contain a week's supply. Some Local Authorities

will not allow drains conveying animal urine into their sewer system, neither will they allow drains to be discharged into a ditch which in turn leads to a ditch along a public highway. Washing down water can be separated from urine by using two gulleys, but a dual drain system is involved which adds to the cost.

With the narrow type dunging channel, referred to previously, a good deal of urine is absorbed by the straw filling it and is carted out with the litter and manure to the dung-shed.

Water Supply—Individual drinking bowls are desirable. In a double standing they should be centrally fixed towards the back of the manger, approximately 2 ft. above the level of the standing floor. Stand pipes should also be provided in the cowshed at suitable points for attaching hose-pipes to when washing down.

Roofs—Metal roof trusses are not recommended as they add to the condensation problem. Steel rusts badly and needs constant maintenance. Well-creosoted timber trusses are better, but precast concrete Portal frames are the cleanest type of roof structure and do not need maintaining after erection. Asbestos sheets are economical for roof covering, but not necessarily the best. When reconstructing old buildings it is better, and often cheaper, to retain and repair tiled and slated roofs than replace with asbestos. Galvanised corrugated iron is not recommended as roofing for buildings housing livestock. Thatch is a suitable roof cover, gives a building a picturesque appearance, but is quite uneconomical for a modern building, apart from being inflammable and a harbour for birds, mice and insects. Roof lights are necessary to a double range cowhouse, having an area of approximately 3 sq. ft. per cow. Asbestos sheet deadlights are the most satisfactory type.

Ventilation—Air outlets are much more important than inlets in a cowshed. With a pitched type of roof the best outlet is through the ridge—the highest point. Special ridge ventilators and outlets are unnecessary with an asbestos roof; it is sufficient if alternate ridge caps are left off along the whole length of the ridge, providing the open slot does not exceed 3 in. in width and is not less than 1½ in. In some cases the ridge capping can be entirely omitted except

for a length over each gable end. A wide building usually indicates a high ridge. If too high the outlets will not function and down draughts occur in cold weather. In addition to ridge ventilation it is also advisable to provide large adjustable ventilators in both gable ends. A tiled roof is an excellent ventilator, provided the tiles are not torched on the underside.

Windows should be constructed either of timber or precast concrete. Whichever type is used the frame should be set $1\frac{1}{2}$–2 in. shorter than the opening, thus ensuring a permanent form of air inlet. If the outer sill is brought through to the inside of the wall, condense off the windows is led out of the building. Metal hopper windows may also be employed but even where they are rust-proofed they are not entirely free from maintenance.

A glass area of at least 4 sq. ft. per cow is necessary where windows are employed in a cowshed.

It is impossible to ventilate a cowshed by natural means other than on a "hit and miss" principle, and all forms of special ventilators and cappings and windows, etc., which claim to accomplish this can only do so under certain wind or weather conditions. The aim should be an airy cowshed at a lower temperature rather than humid conditions at a higher temperature. To mechanically ventilate a cowshed satisfactorily, the building should be designed for the purpose.

Double Sliding Doors—Should be stopped against 14 in. × $4\frac{1}{2}$ in. brick piers, as other forms of door stops all get knocked off in time. The overhead track should be protected with either a precast concrete, or a metal, canopy to protect it from the weather. Sliding doors are always very draughty no matter how well-fitted and it is well to remember the cow in the end standing nearest the wall gets most of the draught.

Manure Disposal—Pits should be sited well away, preferably 60 ft. from the dairy and cow-house on the north side of the building. On free-draining soil, the floor, which should be of concrete, can be about 3 ft. below ground level. It should have an easy ramp down to it to enable a mechanically operated dung fork to handle the manure, and to enable loaded trailers to get out. On heavy soil it is usual to heap

the manure on a concrete slab set at ground level. The slab should be dished and drained to the centre, the drain being connected to the liquid manure tank. It is an advantage to have at least one wall, about 3 ft. 6 in. high, as it enables a mechanical fork to deal more effectively with the remains of the heap.

Manure pits should be roofed over wherever possible.

Farmyard manure weighs from 12 to 16 cwt. per cubic yard.

Yards—Most types of farm stock can be accommodated in a yard, and it is probably the most logical way of housing and feeding them during the winter months. They appear to enjoy better health and are more readily detected when in season. Yards vary in character from a corrugated iron hovel set on a small patch of fenced-off land, to a completely walled-in Dutch barn. In the Midlands and south-east of England, a semi-covered yard is quite suitable. In the wetter areas of the West and colder districts of the North, it is better to cover it over completely. Two-thirds covered area to one-third open is a useful and economic ratio for the semi-covered yard; 22 ft. 6 in. should be the minimum depth of cover. The height on the open side should not exceed 11 ft. and should have a south-easterly aspect, as it enables a beast to make the most of the winter morning sun. Later in the day atmospheric vapour usually clouds it over. Both covered and semi-covered yards should be protected by walls not less than 6 ft. 6 in. high. Open railed fences are a source of draughty and untenable yards. Columns supporting the ends of roof trusses too closely spaced, obstruct and slow down mechanised mucking-out operations. They are often unnecessary and can be avoided by good design.

A plentiful supply of straw is necessary for yarded cattle. The amount varies depending upon the amount of cover provided. A semi-covered yard of a type previously described needs a *minimum* of 20–25 cwt. of straw litter per beast per winter, for the sheltered area only. If the open yard is to be strawed as well, more than double this amount is necessary.

The number of beasts to a yard should be limited to about 20 or 25, as it gives a better and more flexible control of stock, and there is also less risk of damaged teats. All

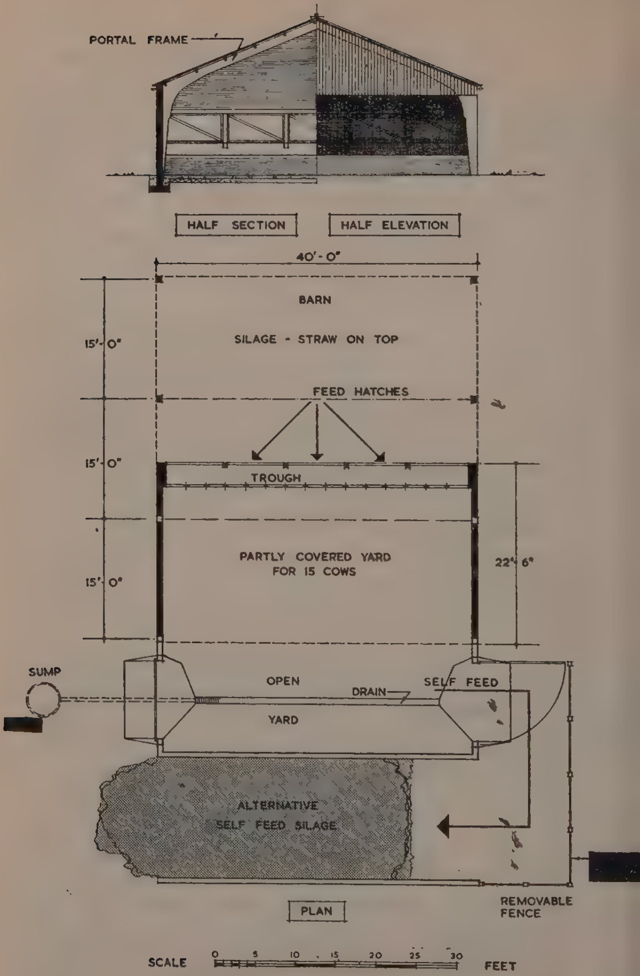

FIG. 27. Yard for self feeding silage.

yarded beasts should be de-horned but even then some breeds are quarrelsome, in which case it is better to reduce the number to 15 or less per yard.

Planning—A yard and parlour system, unless it is very well planned, can be more wasteful of time and labour than a cowshed. Building design and livestock management are closely interwoven, and the layout should provide for different methods of feeding to be tried out in various combinations, such as:—

(*a*) Roots, kale and beet tops, fed in a manger.
(*b*) Hay and straw, fed mangers, or racks, or self fed.
(*c*) Silage, hand fed, or self fed, supplemented with hay and straw.
(*d*) Concentrates, fed in a manger to yoked beasts, or in a milking parlour.
(*e*) Provision for fattening pigs in yards during the summer months.

The total area of a yard, covered and open, should be about 90–100 sq. ft. per beast, excluding manger space. The determining factor is the length of trough which, in the case of fully grown de-horned cows, is 2 ft. 6 in. If they are to be yoked the length is increased to 2 ft. 9 in. Where self feeding of silage is adopted, mangers for hay and straw racks should be planned well away from the silage heap in order that the "master" cow cannot dominate both places at the same time.

Wide undercover feeding passages along the back of yards should be avoided. They increase expense and are draughty. It is better to have the mangers outside the building or, alternatively, feed through the back wall through hatches.

Mangers—Should be constructed like those described for cowhouses, except the fronts should be 3 ft. 6 in. high instead of 6 in., to allow the muck to build up. It is also advisable to erect tubular rails off the front lip, for the whole length of the manger, to prevent beasts from slipping over to their backs in them when bullied.

If pigs are to be fattened in yards during the summer months when the cows are out, permanent pig troughs can be built under the mangers. They take no harm being

filled with muck when the cows are in the yards during the winter.

Water Troughs—Should be fixed at the same height as the mangers in order to allow the muck to build up. If there is more than one yard, the trough should be placed between the two. Less space is then taken up and a timid beast is less likely to be trapped in the corner made by a large trough projecting into a yard.

Yard Bottoms—Under the cover of a roof, a yard bottom may be constructed of rammed chalk 9 in. thick, hardcore 6 in. thick, or concrete 4 in. thick on 4 in. of hardcore. The open area of the yard should be 4 in. concrete on rammed hardcore. The concrete should have a good fall of about $1\frac{1}{2}$ in. in 7 ft. 6 in. towards a drain which runs the length of the yards, and is constructed of half-round glazed channel pipes set 6–9 in. below the surface of the concrete and covered with loose bricks laid flat in a rebate. The top of the bricks should be level with the surface of the concrete. Very little water seems to percolate through straw in an open yard after it has been well trodden.

Gates—Should be at least 10 ft. wide and boarded or sheeted over with corrugated iron to keep the yard as draught-free as possible. Gates should be given three hanging and fastening positions at approximately 9 in. centres so that they can be lifted as the muck rises.

Silage—Silage can be made without recourse to building walls or pits, but where large amounts are made, and stock help themselves to it, consideration has to be given to building both walls and a roof over, as well as to siting. In well-drained soils, silage may be made in a pit, but eventually the bottom becomes soft and the sides crumble, so they have to be concreted. Railway sleepers lined internally with waterproofed paper or, alternatively, manufactured precast concrete slabs bolted together, make good surface silos. Too many cracks and crevices let in the air which leads to a wastage of material. Where precast concrete hollow blocks are used to form the walls they should not be reinforced by vertical steel bars. Brickwork also should not be reinforced with steel wires, unless the inner faces of the wall in contact with the silage are waterproofed, because

silage contains acids which will corrode the steel as well as the concrete surfaces.

The greatest pressure on a silo wall occurs when a tractor is moving over and consolidating the heap at the top of, and near to, the highest part of the wall. The pressure exerted by the material inside the silo is only about a third of this.

If there is any doubt, prop up the side walls when making the heap, especially where they are unduly high.

MILKING PARLOUR

As the hub is to the spokes of a wheel, so should the disposition of the parlour be to a yard or yards. In this position the greatest amount of time and labour is saved. Three different types of parlour are shown in Fig. 28:—

(*a*) The abreast type is the one most commonly used. The step up to the bail should be 9 in. or 10 in., which is not too high for a cow to manage and not too low for a cowman to bend down. One man comfortably operates two of these units, or four cows, at a time. Three is rather too many for one, but not enough for two men. Feeding rations to a cow in a bail slows down milking operations. Where cows are not fed in a bail a small assembly yard is essential as the cows have to be brought to inside the parlour.

(*b*) Two-level tandem parlour. There are several variations and combinations of the unit, and that shown is considered to be the best combination for one man milking 3 cows at a time. In some systems washing stalls are provided but they are unnecessary.

(*c*) New Zealand Herringbone milking bail recently introduced into this country. This type of parlour is only suitable for the larger type of commercial milk producer having a herd of 50 cows or more. Feeding the bail is not possible and all slow milkers have to be culled. Six cows can be milked as a group at a time by one man, whilst another is employed washing the udders of a further group opposite. After each cow is milked out the teat cups are transferred to the cows opposite. Milking times are considerably reduced by this system. Heifers are quieter when sandwiched in between matrons.

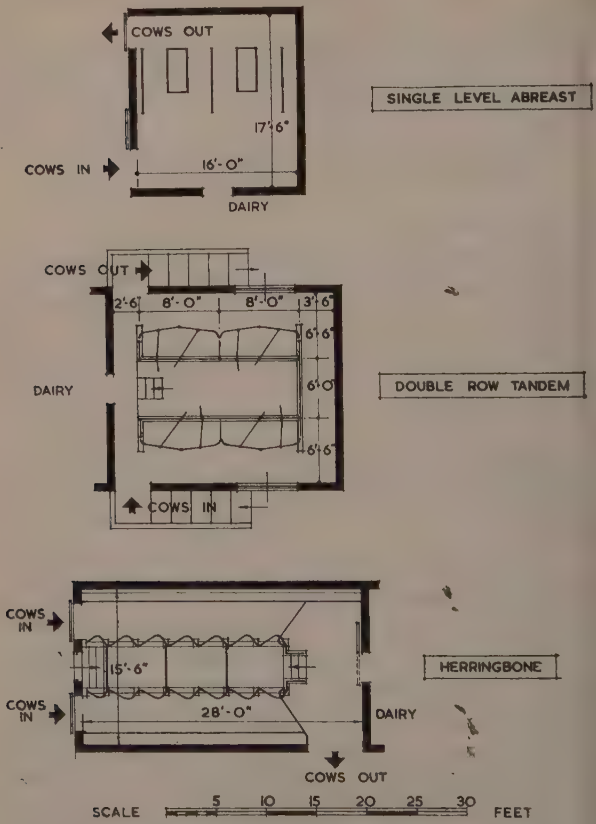

FIG. 28. Milking parlours.

Recording and sampling are more difficult, however, and a small concreted assembly yard is essential.

Floors should be kept up as high as possible and at the same level as the dairy floor, which should also be raised, to facilitate churn handling from bail to lorry. In the case of (*b*) and (*c*) where the men operate from a pit, a light overhead track for churn handling, when an in-churn system of milking is employed, is extremely useful and labour saving.

A directional fan and heater unit should be installed in any milking parlour for the benefit of the cowman, as it can be extremely cold during early morning winter milking.

FARM DAIRIES

These should have a northern aspect and form part of a cow-house, or milking parlour, but clear of sources of contamination. Direct access from a cow-house to a dairy other than by a ventilated lobby should be avoided. There is no objection, however, in the case of a milking parlour. Lighting and ventilation are important features of the design. To obviate excessive condensation ridge ventilation should be provided and the underside of the roof insulated with a sealed waterproof insulator (see Building Data). The height to eaves should not be less than 8 ft. Steel roof trusses, purlins and windows, should be avoided as far as possible. A concrete flat roof over a dairy is also unsatisfactory.

A large, well-laid-out dairy in the form of a single compartment is much more labour saving than dividing the area up into cooling room, sterilising room, tipping lobby, etc., except in the case of a producer-retailer. A rectangular plan provides greater wall space on which to support churn rails, milk cooler, steriliser, electric heating or cooling units, tables, etc. A concrete table cantilevered out from a wall and covered with quarry tiles makes a strong, permanent and easy-to-clean surface on which to dismantle teat cups and gives a clear floor space under. A wash-hand-basin should also be provided with towels. Glass bricks make excellent windows, alternatively, timber or precast concrete may be used.

It requires 3–5 gal. of water, depending on the temperature, to cool 1 gal. of milk. Where there is not a plentiful supply

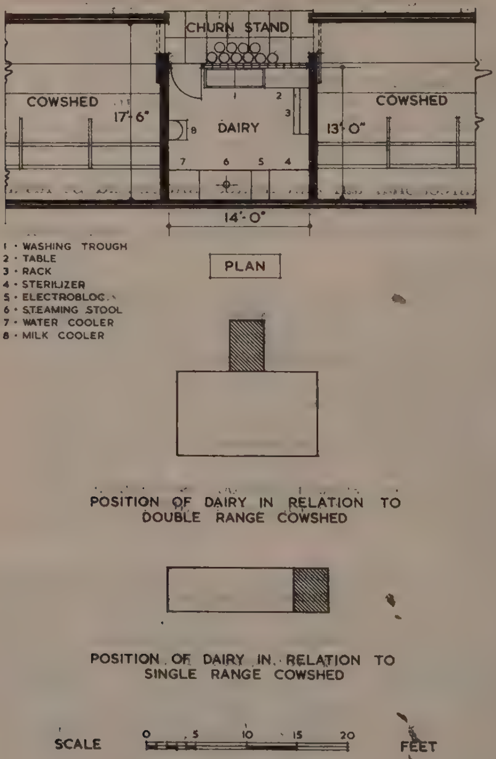

Fig. 29. Layout of dairy.

of water, a chilled water unit may be employed. The open system chills the water passing through it, whilst the closed system uses the same water over and over again. Both systems are operated by motor.

Boiler houses are seldom used because of capital outlay in constructing them and labour required in firing. Electric steam raising blocks are an alternative, although chemical sterilisation in the form of hypochlorites and caustic soda, are becoming increasingly popular.

Sterilising chests should be placed as near to the boiler as possible, particularly in the case of an "electro block," where the pressure of the generated steam is only about 3 lb. per sq. in.

Walls—Should be lined preferably full height or with a dado 4 ft. 6 in. high, of 6 in. × 6 in. white glazed tiles, or screeded with white cement, coved at the floor and wall junction.

Floors should be laid to a single fall of 1–1½ in. in 10 ft. towards the door into an outside channel covered with an open grating. The best material for surfacing a dairy floor is a 1½–2 in. thick screed composed of aluminous, or quick-setting, cement and sand, or, alternatively, 2 ft. × 2 ft. × 2 in. thick precast concrete slabs. Loading banks should be 3 ft. high if possible.

Size of Herd	Floor Area of Dairy	Approximate Rectangular Sizes
Less than 20	180 sq. ft.	15 ft. × 12 ft.
20–40	220–250 ,,	18 ft. × 12 ft.
Over 40	300–350 ,,	20 ft. × 15 ft.

Sterilising chests vary in size and type according to make. A useful average size for 20–30 cows is 3 ft. × 3 ft. × 3 ft., and a large size is 4 ft. × 3 ft. × 4 ft. Provision should be made for opening the door at a 90° angle.

Washing troughs also vary in size and type according to make, a useful average size being 4 ft. 6 in. long × 2 ft. 3 in. wide × 1 ft. 6 in. deep.

Milk churns are now standardised to BSS. 1484 : 1948 with 10 gal. capacity. The height is 2 ft. 2 in. with a diameter of 15 in. Each churn occupies approximately 2 sq. ft. of floor space. Milk may be bulk handled in the future, and when planning a diary consideration should be given to this factor and space allowed for storing two or three days' supply of milk, together with the necessary refrigeration equipment. About 25 ft. super would suffice to accommodate a plant for 20–25 cows.

CALF PENS

These should be well sheltered, airy but cosy, and have a N.–S. longitudinal axis, with a well-insulated roof and damp-proofed floor.

Calves up to three months old should be kept in single pens, having a floor area of approximately 24 sq. ft. Older calves can be run in groups of three or four, in pens double this size. Pen divisions should be 3 ft. 6 in. high, and tubular division rails should be avoided, even along the pen fronts. A small tubular gate about 2 ft. wide, however, enables a calf to look out. If the rails are spaced too far apart a calf may get its head stuck between them. The centre rails may be hinged at the bottom to enable a calf to drink from a bucket fastened to the outside of the gate. The gate should fit closely between the jambs of the opening in the wall, leaving a clearance not greater than $1\frac{1}{2}$ in. each side. Pen division wall tops, and door openings in brickwork, should be fitted with bull-nosed brick. Even if young calves are to be suckled it is better to site the calf house near the dairy, in case of a change of ideas in management.

Walls should be in 11 in. cavity brickwork not more than 5 ft. 6 in. to the eaves. Windows should be omitted and glass bricks used instead. The glass area should be about $\frac{1}{25}$ of the floor area of the calf house. Roof trusses and purlins should be constructed of pressure creosoted timber.

Where pens are on both sides of a centre passage, which should be about 3 ft. 6 in. wide, the floor of the pens should have a 3 in. fall to a shallow gutter formed on either side of the passage, which in turn discharges over an external gully at one end of the building. The passage and floor should be given a longitudinal fall of about 2 in. in 10 ft.

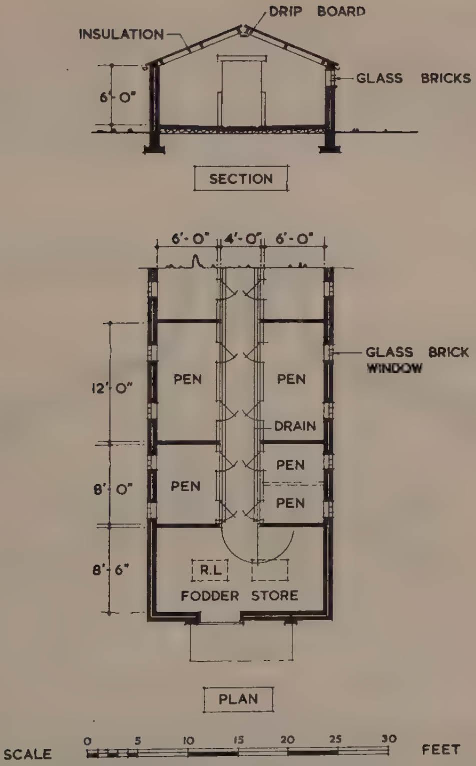

Fig. 30. Calf unit.

Water bowls invariably leak, or overflow, owing to chaff getting under the valve seating and where used should be placed near the gate in order not to wet the bedding. Half-heck doors should be provided at each end of the feeding passage, but in exposed situations a porch should be fitted to the south door for use in winter time. Ridge ventilation is probably the most suitable, using alternative non-ventilated

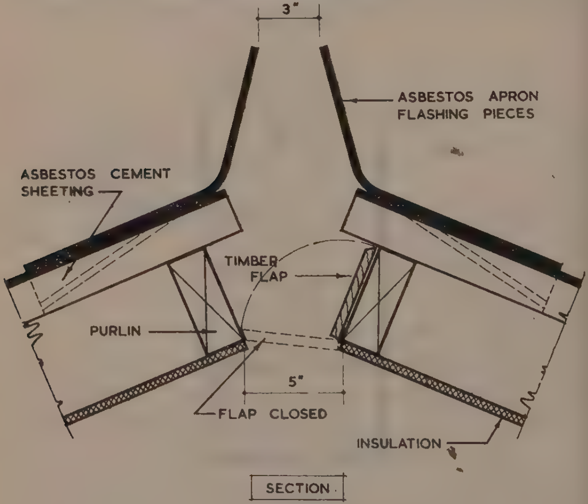

FIG. 31. Open ridge ventilation.

ridge caps, which are the cause of down-draught in certain wind directions, in conjunction with an open ridge (see Fig. 31). The open slit between the ends of the asbestos sheets should not exceed 3 in.

Because of licking, paint, especially lead paint, should not be used on fittings. Avoid building metal fittings such as tubular rails and pipes, etc., into a concrete floor or through a wall, as they act as a radiator in reverse, and quite a lot

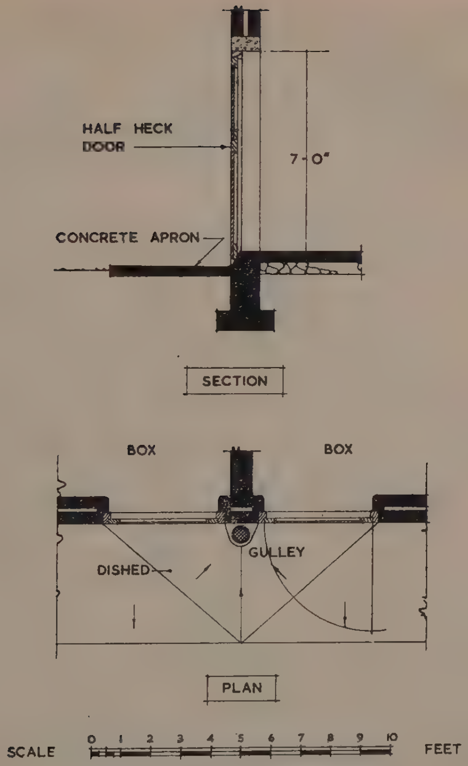

Fig. 32. Loose box drainage.

of heat can be lost from a building in this manner. All internal walls should be whitewashed; it improves the insulation and seals the surface of the brickwork.

Boxes—Should not be smaller than 12 ft. square. A useful size is 12 ft. × 14 ft. and 7 ft. 3 in. to the eaves, which is sufficiently high. The walls should be 11 in. cavity brickwork, the roof insulated, and the floor damp-proofed and laid to fall towards the doorway. The bottom part of the door covers the top part of the step, which has a slightly sloping front. This arrangement obviates the need for a drainage hole through the wall, which is a source of floor draughts and entry for vermin (see Fig. 32). The division wall between the boxes need only be 4½ in. thick provided a 14 in. wide brick pier is formed on one side, near to the centre. The external angles of the pier and the internal angles of brick door jambs should be formed in bull-nosed bricks. A tying ring should be provided in each box about 2 ft 6 in. above the floor. Wooden movable mangers are an advantage provided they are rigidly secured in position when in use. The box can then be used for a variety of purposes. All mangers should be placed in the same wall as, and near to, the door opening, as time and labour are saved when feeding. Fix the water bowl near to the manger because if it leaks the water runs out under the door without wetting the bedding. Windows should be placed high in the wall and be long rather than deep. They should be constructed of precast concrete, or timber. Ridge ventilation may be employed as described for calf pens shown in Fig. 30.

One box should be set aside for isolation and provided with a tying ring in each of the centre of the three walls. A steel, or a stout timber beam, suspended between strengthened purlins is useful for hoisting sick animals. The walls should be rendered in white cement and sand to a height of 5 ft. 6 in. internally, coved to the floor. It is advisable to treat all timber with creosote, and whitewash the internal wall surfaces of all boxes.

BULL PENS

The size of the bull box should be not less than 150 ft. super. A useful size is 12 ft. × 14 ft. × 7 ft. 6 in. high to

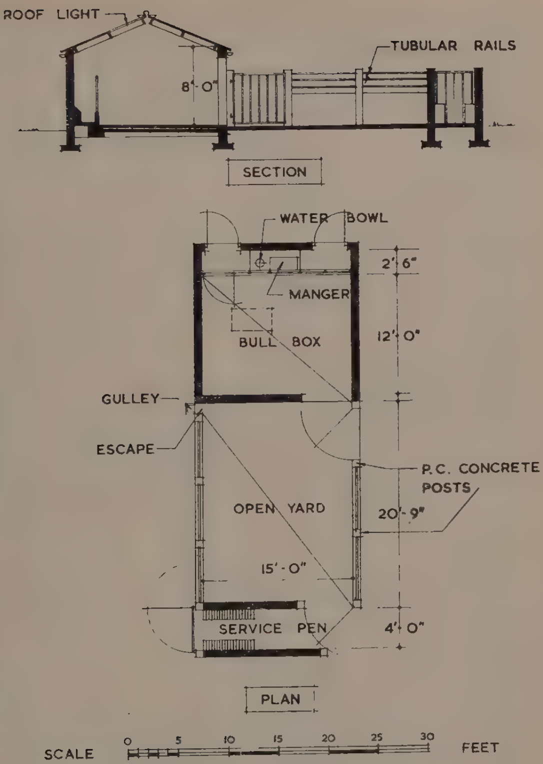

Fig. 33. Bull pen.

the wall plate. The open exercise yard attached to it should not be less than 14 ft. wide × 20 ft. long. The yard should have a south, or south-easterly, aspect and overlook the cow-yard (Fig. 27), as a bull is an inquisitive animal and likes company. The walls should be constructed of 9 in. brick-work and the floor of the box given a fall of 1 in. in 7 ft. 6 in. towards the door, which should have a step down to the yard of 3 in. or 4 in. The yard should have a fall of 1 in. in 10 ft. towards a convenient corner. The walls forming the sides of the yard should be about 3 ft 6 in. high with three lines of $1\frac{3}{4}$ in. or 2 in. diameter tubular rails over, spaced not greater than at 8 in. centres. Vertical steel tubes should not be embedded in brickwork (see Building Data). A service pen should be incorporated as shown in Fig. 33. A safety gap of 12 in. between the wall of the box and the end of the yard wall should be provided in case of an emergency, but both children and dogs can gain access to the pen by the same means. A de-horned bull can often slip his head through a yoke, and as precaution it is advisable to build a metal ring and chain into the wall of the feeding passage opposite the feeding trough, so that it can be fastened to the ring in his nose thus providing additional security when cleaning out yard and pen. A manger, with a yoke and water bowl attached thereto, should be provided, set about 18 in. or 2 ft. above floor level. The underside should be bricked up, or concreted solid, otherwise a bull will soon have both off the wall. The window or glass bricks should be wide and short and built high in the wall. Too many doors in a bull pen are a source of danger because it is not known where the bull is until the door is opened. The system shown in Fig. 33 is a good arrangement. The doors are in a convenient position for both yard and box, which are easily cleaned out in safety. The outer door should be framed, $2\frac{1}{2}$ in. thick, hung on cast steel strap hinges and fitted with two strong fasteners. A bull plays with a sliding door and soon has it off the track.

CROP STORES

DUTCH BARNS

These are made to manufacturer's own standard widths, heights and dimensions and depend upon the material

used and type of design employed. The material may be timber, steel or precast concrete, and sometimes two materials are used in combination, such as timber roof trusses and a precast concrete frame.

The design may embody a curved roof truss, a pitched roof truss, or a portal frame. The first should be properly designed and well made, otherwise it will spread and collapse under a heavy snow load. The pitched roof truss is probably more expensive, but more rigid, though it does not provide the same amount of head-room as the curved truss. A portal frame relies on its shape and rigidity for strength, and does not need a roof truss, a most useful feature, as it provides clear head-room from floor to ridge along the whole length of the building. Projecting eaves are expensive to construct and give very little additional protection.

Roofs may be covered with either galvanised corrugated iron sheets, not less than 22 gauge, or corrugated asbestos sheeting. Vertical sheets in gable end and wall cladding may be reduced to 24 gauge. Asbestos is not a suitable material for wall cladding as it is so easily broken.

Steel dutch barns and galvanised iron sheets need regular maintenance, particularly where atmospheric pollution is severe.

Eaves, gutters and down-pipes are essential, and the

DUTCH BARN CAPACITIES PER BAY OF 15 FT. WIDE 15 FT. EAVES

	Span	
	30 ft.	40 ft.
Loose straw—3½ lb. per cubic foot	10 tons	14 tons
Baled straw (medium density) 6¾ lb. per cubic foot	20 ,,	28 ,,
Loose hay (based on 8 lb. per cubic foot)	23 ,,	32 ,,
Baled hay (medium density, based on 12 lb. per cubic foot) ...	35 ,,	48 ,,

rain-water conveyed to a ditch, or soakaway, at least 7 ft. 6 in. clear of the building. See Building Data on drains.

To avoid damage to stanchions, the feet should be protected by concrete haunchings for at least 2 ft. above the ground. Steel stanchions are usually set in a concrete base, which for a large barn is 3 ft. × 3 ft. × 3 ft. Some types are bolted to the top but are more expensive. Portal framed buildings, particularly the precast concrete framed type, need a deeper foundation.

GRAIN STORAGE

Dried grain may be stored loose on a barn floor, in sacks, or in bins or silos. The first method is only suitable for small quantities of grain owing to the labour factor in handling it. Grain in sacks cannot readily be stacked more than three or four high, therefore a large amount of floor space is necessary. A dutch barn with a lean-to on one, or both, sides, and suitably sheeted down on the exposed sides, makes an economical structure. This is also a useful type of building in which to house grain bins. It should be at least 14 ft. to the eaves, or 16 ft. where a roof truss has tie bars across.

Where grain is already being handled in sacks, it can be readily dried on a sack drying platform, or on the tunnel principle. The former consists of a precast concrete sectional platform raised 9 in. or 12 in. above the floor. Each alternate section has a rectangular hole through it over which a sack is laid, air is then blown through from below, to dry the grain.

An alternative and simpler method is to blow air through a tunnel formed of sacks laid against an aperture made through a wall. The opening should be about 18 in. square, the bottom being 6–9 in. above the floor. A better way is to build an 18 in. diameter, or larger, pipe through the wall, 9 in. above the floor, so one end of it projects 6–9 in. beyond the face in order to reduce air loss between sacks and wall face. Air is blown through the aperture by means of a fan and heater unit on the other side.

Both methods are suitable for about 75–100 tons of grain. Beyond, the labour factor in handling and turning the sacks becomes rather high. Loose, or baled, hay can be dried in

small quantities as well in both these systems, providing the layout is planned for it.

Where large quantities of grain are stored, it is necessary to reduce the moisture content to 14 per cent. before it can be safely stored. This can be accomplished by either drying the grain *in situ*, in storage bins, or drying the grain first and then storing it in sacks, or bins, afterwards. Storage bins can be constructed of metal, timber, or precast concrete, circular or square on plan. Metal bins are suitable for storing or drying grain *in situ*; timber and precast concrete are more suitable for storage only. Circular bins are stronger and can be more economically constructed to a larger size than square bins, but they waste about 23 per cent. of floor space.

Where grain is dried before it is stored, some form of drier is necessary. Two types are generally used, the first being a circular bin constructed of mesh, having a smaller diameter mesh tube part-way up the centre through which air is blown. As the depth of grain between the inner and outer mesh is constant, quicker drying can be obtained. The method is suitable for the smaller farmer as the unit can be increased. The second type is the platform drier, where a continuously moving stream of grain is dried by blowing hot air through it. The plant is expensive to buy and install and is usually employed where the quantity of corn to be dried is fairly large, or where contract drying for other farmers is undertaken. The plant, however, can be readily modified to dry grass, in addition to grain. With this type of plant air is heated by means of oil, or coke fired, heating units and is distributed by means of fans and ducting.

Except for the continuous dryer, the usual method of drying grain is to blow dry air through it by means of a fan and heater unit operated electrically, or by means of a tractor. In the latter case the fan can be driven by a tractor housed in a small shed open on one side. When the tractor is working cold air is drawn from outside over the engine and radiator, which slightly raises the temperature of it, as it is drawn into the fan.

Air intakes should always be located outside the building where corn, or hay, is being dried, otherwise moist air is constantly being re-circulated around the building and little

drying takes place in consequence. The intakes should be placed on the leeward side of the building and protected from driving rain by means of louvres.

It is advisable to turn grain occasionally when it has been dried *in situ*, particularly after a wet harvest, and an additional bin is often provided for the purpose.

Planning—When a tanker combine is used it is more economical to handle the grain mechanically from field to farm gate as the saving in labour is considerable. Even where the capital is not immediately forthcoming provision should be made for a later extension of the system.

Furthermore, the economic advantages of mechanical handling are usually extended to hammer mills and mixing machines. Provision should therefore be made for extending both the conveying system and the building if necessary.

Careful consideration should be given to the layout of roads and approaches to the grain reception pit which is the link between the field and the building. A good deal of time can be lost in manoeuvring tractors and trailers into position if they are badly placed.

It is advisable to site the longitudinal axis of the building west and east to give a west aspect to one gable end in which doors should be provided to create draught through the building when drying is in progress. The wet pit dresser and sacking off space should be on the east end. The site should be level as sloping ground increases the building cost enormously.

A 10-ton self-emptying hopper will be necessary for bulk despatch of grain off the farm. The hopper can be constructed in timber and raised to give a minimum clearance of 14 ft. 6 in. between the ground and the outlets at the bottom. A corrugated iron roof should be provided over the hopper and conveyor if it is erected clear of the building.

Sack storage space is useful, particularly where grain is handled in small lots around the farm. A small office, or even a large cupboard, is also useful for housing moisture meters, temperature spears, records and papers, etc.

Foundations—See Building Data. Prefabricated bins of metal and timber, or precast concrete, can be erected off a thickened concrete floor, or a dwarf wall. The floor should not be less than 4 in. thick, reinforced with steel

mesh. An excess of steel adds nothing to the strength of concrete, the accurate placing of it is much more important. Dwarf walls should not be less than 9 in. thick and built off a strip foundation.

Floors—Are usually constructed of reinforced concrete. See Building Data.

Where grain is dried *in situ* a false floor should be provided in the bins. An economical way of constructing is to lay 18 in. × 9 in. × 9 in. precast concrete hollow blocks flat on their sides in rows 18 in. wide, leaving intervening strips about 12 in. wide covered over with wedge wire. The top of the blocks can then be screeded over in cement and sand to the thickness of the wedge wire which is held in position by it. The perimeter of the bin wall should be lined with solid blocks and the wedge wire strips should stop against them.

An alternative is to lay 12 in. × 12 in. malt kiln tiles over the whole area of the bin floor, on top of bricks set on their ends. One brick supports the corners of four separate tiles.

In both cases sections of the floor should be made removable for cleaning out dust and rubbish which collects in the space below.

Bins—Precast concrete blocks are unsuitable for the construction of grain bins, as it is difficult to control expansion and contraction. Reinforced brickwork is sometimes used but the size should not exceed 10 ft. 6 in. × 10 ft. 6 in. × 12 ft. 6 in. high in 9 in. brickwork. The high standard of workmanship necessary for their construction is not easily found in many rural areas.

Steel and aluminium bins are satisfactory either for grain storage or *in situ* drying. Bins built up of precast concrete units make useful storage bins, but it is extremely difficult to make, and keep, them free from air leaks where they are employed for drying grain *in situ*. Plywood and timber also make satisfactory storage bins, and can be erected in large sizes.

It is advisable to provide an extra bin, or two of a smaller size, rather than construct a fewer number of extra large bins.

Ventilation—A considerable amount of moisture is removed from grain in a wet season and adequate ventilation

must be provided at the ridge and the gable ends of the building. Pipes and ventilators are totally inadequate for the purpose. All doors should be left open in order to induce a draught through the building where the drying plant is in operation.

Grain Pit—Grain is tipped into a pit either by reversing a trailer to the edge and shooting the grain in, or by laying steel tubes, or steel beams, on top, over which a tractor and trailer runs and on to which grain is tipped where it falls through into the pit below. A good deal of mud is brought in off the tractor wheels in a wet season, especially on heavy land.

The pit should be built as far out of the ground as possible and a ramp built up to it. On a level site about 2–3 ft. is the economical limit. To give a 45° angle between the inclined faces of the three sloping sides of the pit it should be rectangular on plan, the short side being about three-quarters the length of the long side. The pit sides should be formed in concrete 3 in. thick and covered with three coats of natural rock asphalt in three separate layers with broken joints. A 3 in. thickness of concrete should then be laid over it. The asphalt must be finished 3 in. *above* ground level.

The elevator pit should be at least 6 ft. × 3 ft. and deep enough to enable the boot of an elevator to fit under the grain outlet at the bottom of the grain pit. The pit can be constructed in engineering bricks 9 in. thick, lined externally with natural rock asphalt in a manner already described.

Vermin—Every precaution should be taken to prevent entry of birds and rodents and close fitting chicken wire doors and guards over all ventilators should be a permanent feature of the structure.

Both rats and birds gain entry from the eaves under the corrugations of the asbestos roof. The ends of the asbestos sheets should be firmly bedded in cement along the top of the walls.

Small pockets and crevices left in the brickwork, and under conveyors, are all breeding grounds for grain weevil and other destructive pests.

Grain in sacks may be left several months under cover at 16–18 per cent. moisture content. Stored in bins, in

quantity, it must be reduced and maintained at 14 per cent.

Dry grain flows freely by gravity at an angle of 45°, but over 20 per cent. moisture content the angle of flow is nearer 50°.

TABLE 76 : GRAIN SILO CAPACITIES

Circular Silos	Square Silos			Capacity per foot of heights		
				Tons		
Base Dia. Area	Base	Area	Qtrs.	Wheat	Barley	Oats
9 ft.	8 ft. × 8 ft.	64	6	1·3	1·2	0·9
11 ft.	10 ft. × 10 ft.	100	9	2·0	1·8	1·3
13 ft.	11 ft 6 in. × 11 ft. 6 in.	132	13	2·9	2·6	1·9
14 ft.	12 ft. 6 in. × 12 ft. 6 in.	156	15	3·3	3·0	2·2

TABLE 77 : WEIGHT AND MEASURES OF VARIOUS CROPS

Crop	Weight per bushel	Weight per qtr.	Quarters per ton	Cu. feet per ton	Weight per cu. foot
	lb.	cwt.			lb.
Wheat ...	63	$4\frac{1}{2}$	$4\frac{1}{2}$	46	48
Barley ...	56	4	5	51	43
Oats ...	42	3	$6\frac{3}{4}$	70	32
Rye	57	4	5	51	44
Peas	63	$4\frac{1}{2}$	$4\frac{1}{2}$	46	48
Beans ...	66	$4\frac{3}{4}$	$4\frac{1}{4}$	43	51
Linseed ...	54	4	5	51	41

GRASS DRYING

The size of the building depends upon the type of drier to be installed. A Dutch barn with a lean-to on either side fulfils most requirements. Provision should be made for the reception and handling of wet grass under cover and also for storing it after it has been dried. Space must be provided for storing either coke, or oil fuel, as convenient to the furnace as possible. Sometimes grass drying installations are also used for drying grain, in which case a wet grain receiving pit, and storage space for grain in sacks, or in bins, will be necessary in addition. Particular attention must be paid to fire risk, and for this reason it is better to isolate the building from the remainder of the farm. Asbestos is a better cladding material than galvanised corrugated iron for a structure of this kind. Bitumen-covered metal sheeting of any sort should not be used owing to fire risk.

Space required for dried grass meal in bags 6–7 cu. ft. per cwt. or 130 cu. ft. per ton. In bales 8–10 cu. ft. per cwt. or 180 cu. ft. per ton.

POTATO STORAGE

By storing a potato crop in a building it is possible to handle it under cover in adverse weather conditions. New buildings designed for the purpose whilst an asset are not always necessary and a Dutch barn, or an old shed, or stable, providing it is high enough, is sufficient. Before buildings are used for such purposes they should be examined by a building specialist qualified to give an opinion on their strength and stability.

Indoor storage may be divided into two types: "shallow" where potatoes are stored from 6 to 8 ft. in height, and "deep" where they are stacked over 8 ft. and up to 12 ft. high. Over 12 ft. it becomes increasingly uneconomical owing partly to the cost of making a building strong enough, and because of the physical difficulties of stacking potatoes higher. In both cases 3 ft. headroom must be allowed over the stored crop at eaves level.

Bottom ventilation is not essential for potatoes in shallow storage but provision should be made for it all the same, in case of a wet harvest. It is necessary for deep storage.

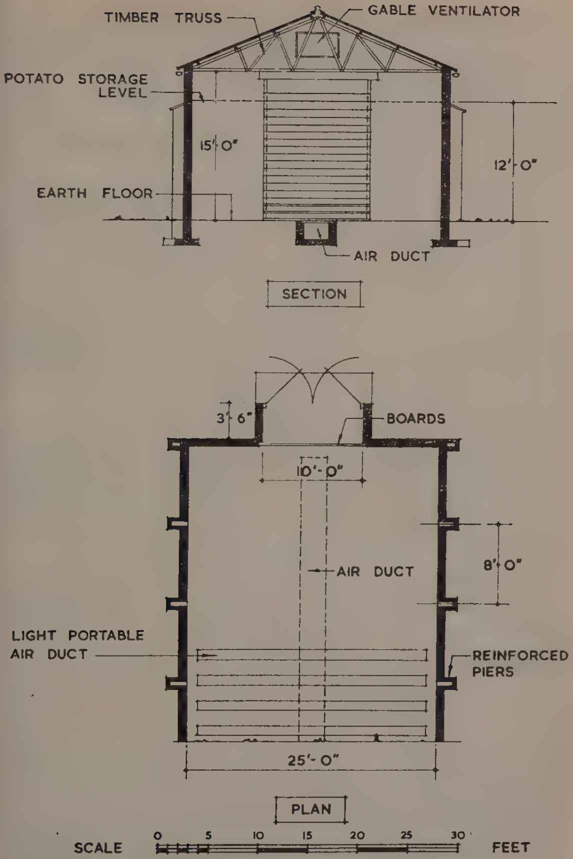

FIG. 34. Potato store.

Forced draught is sometimes used for ventilating potatoes in deep storage but it does not prevent sprouting taking place unless the temperature can be kept between 35° and 40° F., which is seldom possible in this country, unless accompanied by some form of refrigeration. Sprout depressants can be used.

Potato crop shrinkage is some 2 per cent. greater when stored in a building compared with a clamp, but in wet seasons there is less loss from wet rot.

As potatoes can only be stacked from two ends of the building no more than two varieties can be stored, but if in addition a central door is provided on the side wall it is possible to increase the varieties to three. Too many doors complicate the structure and increase building costs.

A potato store especially constructed for the purpose is usually unoccupied between May and September but if mechanical ventilation and a heater unit are incorporated it may be put to other uses such as a broiler or mushroom house or for poultry rearing, if the building is designed for it.

Planning—Adequate roads and accessibility to the building, given under Grain Storage, are an essential feature of the layout. Economies can be effected in construction where the building is planned in association with, or forms part of, a grain storage plant. The fan unit for the latter can also be used for blowing cold air through potatoes in deep storage, an advantage during a mild winter.

Construction—The same high standard of construction necessary for a grain storage building is also needed for the construction of potato storage buildings. The internal width between the walls should not be less than 25 ft. in order to provide ample working space, and an economic structure. The length depends on the amount and the number of varieties stored.

Walls should be of 9 in. thick reinforced brickwork (see Building Data), buttressed by 18 in. × 14 in. brick piers spaced at intervals not greater than at 12 ft. 6 in. centres. The piers may be formed of a $4\frac{1}{2}$ in. brick skin cored internally with concrete reinforced with vertical mild steel bars not less than $\frac{5}{8}$ in. diameter in each corner. The internal walls should either be tarred, or painted over with bitumen, and then lined with 2 in. thick wood wool slabs secured to the wall by

means of galvanised iron nails. The internal face of the slabs should be rendered in cement and sand to protect them from damage. Alternatively, the walls may be lined with straw bales but a loss of approximately 12 per cent., according to the thickness, storage capacity is entailed by doing so. Triangular openings, approximately 14 in. sides, formed at suitable intervals along the length of the wall, at floor level, provide the necessary bottom ventilation. They should be covered over with chicken wire to prevent vermin entering, and closed by means of a small door in frosty weather. The distance apart depends on the depth of storage, and is based on 2 sq. in. of free opening per ton of potatoes stored, or at approximately 6 ft. 6 in. centres per 8 ft. depth of storage.

Light slatted timber triangular ducts about 7 ft. 6 in. in length and having approximately 18 in. long sides are placed on the floor, end to end, starting against the triangular ventilator and taken across the width of the building. The first 18 in. or 2 ft. of the slatted duct nearest the wall should have a solid surface to prevent air loss between the face of the wood wool slabs and the potatoes. Some types of duct can be made to be taken apart and stored flat when not in use. Where a fan is employed for forced bottom ventilation, a central duct approximately 2 ft. 6 in. wide running the length of the building should be formed in concrete below the level of the floor and covered over with loose boards. If a board is removed at intervals along the length of the duct, the slatted ducts previously referred to can be set over the opening, and air fed into it from below. The air intake must be outside the building and protected from the weather.

A considerable amount of moisture is given off by potatoes stored in buildings and for this reason top ventilation must be provided at the rate of 3 sq. ft. per 100 tons of potatoes stored. This ventilation is best obtained by providing openings in the gable ends which can be covered over with a close fitting drop down, or sliding door, for use in frosty weather.

The roof trusses should be constructed of pressure creosoted timber having a tie bar. The roof truss should not be of the scissor, or hair-pin, type which adds lateral thrust on the walls. The floor may be of bare earth, concrete or hardcore being unnecessary.

Sliding doors should not be used, but close fitting folding doors hung in a wooden frame set between two projecting buttresses. About 18 in. or 2 ft. 3 in. behind the doors a $4\frac{1}{2}$ in. vertical rebate should be formed in the brickwork against which are placed 9 in. × 2 in. retaining boards set edgewise, one above the other, as the potatoes are stacked up. The bottom three boards, if set at an angle of 45° to the horizontal on a piece of angle iron bolted to the wall, may easily be withdrawn to enable the potatoes to be removed from the bottom of the stack.

Where potatoes are stored in an existing building, all large openings should be filled in, with high density straw bales. The top bales should be covered with felt or tarred paper to prevent the entry of rain.

One ton of potatoes occupies approximately 56 cu. ft. Heat is produced at the rate of 35–50 B.Th.U. per ton per hour, depending on the temperature of the store. The ideal storage temperature is approximately 40–45° F., which cannot be maintained for lengthy periods in this country.

Potato Chitting House—Most types of glass-house serve for chitting potatoes, and vary in width from 16 ft. to 22 ft. and from 7 ft. 6 in. to 9 ft. at the eaves. The interior should be free from internal columns, as in the case of a vinery type glass-house, which obstruct movement and stacking. Double doors wide enough for a tractor save time and labour. Sliding doors are draughty and during a cold easterly wind the potatoes will get frozen. Glass-houses are made in steel, aluminium and timber framing, the latter probably being the cheapest. The floor should not be concreted, then the building may be used for other purposes between chitting times, or when potatoes are omitted from a rotation. A costly heating system is not necessary, paraffin lamps or electric tubular heaters keeping the temperature from falling below 40° F.

Potatoes can also be chitted in old stone barns and cottages with the upper floors taken out. From an insulation point of view they are often ideal. Chitting is then obtained by movable fluorescent lamps. Potatoes should be stored in boxes to a height of 8 ft, 10 ft. or 13 ft., which are multiples of the 5 ft. and 8 ft. standard type fluorescent tubes. It is difficult to stack boxes over 10 ft. in height without a

machine, furthermore, there is a tendency for them to topple over if not stacked vertically, or if taken too high, especially when erected off an earth floor. The tube should be of the "warm white" type and hung vertically from a steel wire and moved laterally every few days. Electric fan and heater units usually provide sufficient heat and air movement in either glass-houses or barns. The bottom row of boxes should be empty as it is difficult to light them adequately. Boxes should be placed in double rows, end to end with a 2 ft. passageway between them and this usually determines the width of the building.

The size of potato chitting trays in general use is 2 ft. 6 in. long × 1 ft. 6 in. wide × 6 in. high. The actual depth at side of the boxes is 3 in. plus 3 in. of leg above

Three trays hold approximately 1 cwt. of potatoes.

IMPLEMENT SHEDS

Implement sheds may be of three types, (*a*) long narrow open fronted sheds, (*b*) large totally enclosed buildings, and (*c*) Dutch barns. The latter does not provide much protection against the weather, unless sheeted to the ground along one side and two ends, in which case it becomes an expensive structure. The only implements needing a high roof are the combine harvester, two or three types of non-folding elevators, and livestock carrier. The majority of farm implements are less than 6 ft. in height and can be accommodated in any building high enough to take a tractor with a cab fitted to it. The totally enclosed shed is expensive to construct and the cost is only justified on a large arable farm. Furthermore, if made entirely of metal, or concrete blocks, excessive condensation takes place inside, unless well ventilated. The long open-fronted type is in most common use. It is inexpensive to construct and ideal for either trailed or mounted implements, tractors and trailers. Simple implements made mainly of cast iron, or carbon steel such as rollers, discs, ploughs and harrows can be left in the open provided the vulnerable parts are protected with grease.

Planning—New open-fronted sheds and Dutch barns should face south or south-east. The orientation of the totally enclosed shed is not so important provided the main entrance is not on the weather side of the building. Accessability to any type of implement without having to move

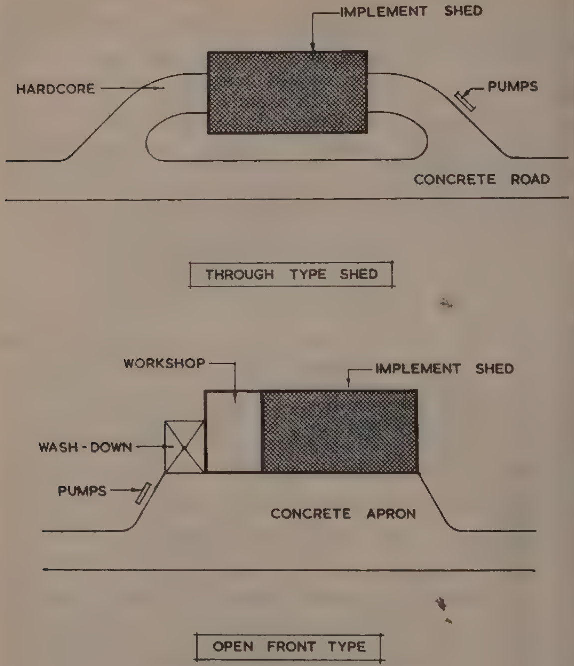

FIG. 35. Implement shed.

half the bay in front, is the most important factor. A totally enclosed shed should be set to one side of, and parallel with, a farm road to enable a tractor to be driven straight into the building hitch the implement and drive out the opposite end (Fig. 35). The implements are usually set out at an angle of 45° to the access road through the shed, in order to reduce manoeuvring space.

An open-fronted shed should be sited alongside a farm road and have a concrete apron in front of it at least 15 ft. deep, to enable implements to be drawn out for servicing,

TABLE 78—AVERAGE SIZES OF FARM IMPLEMENTS

Implement	Length		Width		Height		Area in sq. ft.
	ft.	in.	ft.	in.	ft.	in.	
*Medium Tractor ...	11	3	6	0	7	6	68
*Tracklayer	10	6	5	6	6	6	58
Row Crop Tractor ...	11	3	6	0	7	0	68
Harrows	5	0	8	6	2	9	42
†Two-furrow Plough ...	6	6	2	4	3	6	15
†Three-furrow Plough ...	7	6	4	6	3	6	24
Disc Plough	5	4	2	9	3	8	12
Cultivator	5	0	7	0	2	9	36
Ridge Plough	3	0	8	0	3	6	25
Trailers (2-wheel) ...	13	9	6	4	4	3	86
Combine Drill (13-coulter)	7	0	10	6	4	0	74
Potato Planter	5	0	7	3	4	9	36
Fertiliser Drill	7	1	9	0	3	5	63
Potato Spinner	4	9	6	4	3	9	30
Crop Sprayer	3	0	6	8	5	8	20
Swathe Turner	7	0	10	0	3	6	70
Sack and Bale Elevator	12	0	5	5	6	6	66
Mower (5 ft. cut) ...	4	3	7	6			
Sugar Beet Harvester ...	12	0	8	0	7	6	160
Pick-up Baler	18	0	8	9	4	6	158
Combine Harvester ...	23	6	10	0	11	6	235

* Without a cab. † Mounted implements.

or parking, without obstructing the traffic on the farm road. Columns along the front should be avoided and it is possible to obtain clear spans of 40 ft. by using timber lattice girders, giving greater storage space, increased manoeuvrability, and less damage to both tractors, implements, and building. The minimum depth, or width, of the building should be 22 ft. 6 in. and a maximum of 10 ft. from ground level to eaves.

Workshop, tractor shed, fertiliser store and fuel storage should all form part of the same structure. To save space two tractors can be housed in a workshop.

Construction—A precast concrete portal frame with breeze block panel infilling makes an excellent shed. Alternatively 18 in. × 9 in. × 9 in. precast concrete block cross walls built at 40 ft. centres with a timber lattice girder over, supporting wooden rakers provides a column-free structure. The floor and apron should be constructed of concrete, as dust from ash, or hardcore, floors gets into the bearings of an implement, especially in an open-fronted shed. Walls should not be constructed with asbestos sheets. Provision should be made for water, electric lighting and power points, and a compressed-air line.

Workshop—Should be at least 22 ft. 6 in. × 20 ft. if it is to be of any use, it can form part of the implement shed but should be separated from it by a dividing wall. Windows should have a north aspect and the work bench should be set under them, an inspection pit, cupboards for tools, and a stove should also be provided. In a convenient position near to the workshop a dished concrete apron, at least 14 ft. square, should be formed to enable implements, and tractors, to be washed down before servicing and repairs. Sliding doors the full height of the eaves are also necessary. The floor should be laid dead level in concrete 4 in. thick finished with a steel float. An overhead steel beam capable of supporting at least 15 cwt. is also a great advantage.

Fuel Store—Should be sited near to the workshop. Petrol tanks must be kept below the ground and are subject to regulations laid down by local authorities. Diesel oil and vaporising oil may be stored in tanks above the ground, and can be delivered to tractor fuel tanks, through a flexible pipe, by gravity. Elliptical, or circular, fuel tanks weather

better, and are stronger, than rectangular tanks. They should be set on top of a dwarf wall 9 in. thick, and about 4 ft. 6 in. high. The tanks should not be set level but given a longitudinal fall of about 3 in. to a drain cock provided at the low end, opposite the delivery pipe, where the sludge and water can be drained off. A built-in metal ladder gives access to the top of the tank to enable dip stick readings to be taken and a connection made to the delivery lorry. Fuel oils cannot be raised more than 10 ft. from the delivery lorries. Lubricating oils may be stored in drums in a metal cabinet near to the fuel tanks, or directly underneath them, on a concrete base. Fuel tank sizes vary with type but should be large enough to hold not less than a month's average consumption. Diesel fuel should not be stored in galvanised iron tanks as chemical action takes place which is likely to give rise to fuel troubles in an engine.

TABLE 79: SIZES AND CAPACITIES OF RECTANGULAR TANKS

Size	Dimensions	Weight (full)
250 gall.	4 ft. 9 in. × 3 ft. × 3 ft.	1 ton
400 „	4 ft. 9 in. × 4 ft. × 4 ft.	1 ton 13 cwt.
600 „	6 ft. 6 in. × 4 ft. × 4 ft.	2 ton 7 cwt.

Fertiliser Store—Since fertilisers are mainly applied by fertiliser drills or combine drills the position of the store should be near the implement shed, or form part of it. Bags should not be placed against outer walls or stacked on concrete or earthen floors. An air space of at least 18 in. should be left between walls and bags, and 6 in. beneath the bottom sacks and the floor. A well-ventilated boarded floor is ideal for the purpose although straw bales set on concrete are sometimes used and are cheaper. Sacks can be stored six to ten sacks high, laid flat. If they are laid higher the bottom layer of bags becomes too consolidated for use. Alleyways should be provided between different types of fertilisers. Fertilisers containing sulphates eventually destroy concrete and mortar, especially in the presence of moisture. Fertilisers should never be stored in a totally

enclosed corrugated iron shed because condensation drips back on to the bags.

One ton per square yard, eight sacks high, is a useful unit to work to in calculating the size of the store.

SHEEP EQUIPMENT

Dips, handling pens, and perhaps a shearing shed for a large sheep farm, are the only structural equipment needed. The main essentials of a dipper are a collecting pen with sorting race and drafting pens to enable the flock to be arranged in the right order for dipping. The dipping bath should be designed to suit the breed and number of sheep. It should have a draining pen attached, to enable the drip to be returned to the bath. A short swim bath, about 11 ft. long at the top, with a 6 ft. long sloping exit ramp at one end meets most needs. It is usual to rib the floor at the footbath, and the slope up from the dipping bath, to ensure the liquid gets between the hoofs of the animals. For flocks of over 1000 the long swim bath is more suitable, the length in this case being double that given for the short version. The depth of fluid should be 3 ft. 6 in. to 4 ft. 6 in. and the quantity 250 gal. and 500 gal. respectively. The widths should be 2 ft. 9 in. at the top tapering to 12 in. at the bottom, and 2 ft. tapering to 9 in. for the long bath.

The bath can be constructed in 4 in. concrete, or bought ready made in galvanised iron ready to install in the ground. The bottom should be provided with a drain for emptying, and a plug. The liquid dip may not be taken into any drainage system or watercourse, but should be taken to a soakaway provided for the purpose. The draining pen consists of a 4 in. thick concrete apron, about 7 ft. 6 in. wide by 15 ft. long, drained to the centre where a trapped gulley returns the dip to the bath, but not the droppings.

The handling pen fences should be post and rail not less than 4 ft. high. The rails should be 3 in. $\times$ $1\frac{1}{4}$ in. fastened to 4 in. $\times$ 4 in. posts, on the sheep side of the fence, to prevent injury. The rails should be spaced at approximately 10 in. centres.

HORSE ACCOMMODATION

Stables should be from 16 ft. to 18 ft. deep with stall divisions at 6 ft. 6 in. centres. Swinging bales are sometimes

preferred to fixed stall divisions, or when horses are used to working together and are docile the divisions can be omitted.

The walls should be 9 in. thick; see Building Data Brickwork. Height from floor to wall plate should be 7 ft. 6 in. or where there is a loft over 8 ft. 6 in. floor to ceiling.

The floors, which are subject to hard wear, should be of good roughened concrete 5 in. thick on 4 in. hardcore, with a horizontal damp-proof course between. The heel panel under the horses' hind legs should be either 6 in. granite setts or Staffordshire blue bricks set in cement.

The stall floor should be given a fall of $1\frac{1}{2}$ in. to a longitudinal centre gutter constructed 10 ft. from the manger wall. The rear gangway should also be given a fall towards the centre gutter.

Either windows giving 6 sq. ft. of glass for each animal or roof lights giving 4 sq. ft. can be used.

Doors should be 7 ft. high by 4 ft. wide in the clear, divided with lower half 4 ft. high and upper half 3 ft. high.

Stall divisions firmly secured to floor and manger front should be 8 ft. long by 6 ft. 6 in. high, at the manger end, sloping down to 5 ft. high at heel posts. Hardwood kicking panels 3 ft. × 4 ft. should also be provided. Heel post 6 in. × 6 in. with boarding flush with post. Where there is a loft the heel post can serve as a supporting column for a floor beam, as it enables the dimensions of the floor joists to be reduced.

Mangers and hay racks should be 3 ft. 3 in. to 3 ft. 6 in. from the floor to the top of the curb. A combined manger and hay rack, suitably divided, should be provided in preference to hay racks above the manger, which are not recommended. The manger should be 18 in. wide by 12 in. deep, with baffled fresh air inlets under it. A tying ring should be fixed to the front curb of the manger.

Loose boxes for training horses should be approximately 18 ft. × 18 ft. lined internally to a height of at least 5 ft. 6 in. with 1 in. T. & G. boarding on creosoted battens plugged to the wall.

ROADS AND FENCES

Within a farm there are usually three types of road, the access road connecting the farmstead with the highway, the roads which link the buildings together, and the internal

roads serving the fields. Each serves a different purpose and needs different treatment.

The access road is the artery of the farm and needs not only a good layout but a reasonably good surface. The width should not be less than 8 ft. 6 in. or 9 ft. If a roadway is made too narrow there is a tendency for it to be cut into three strips, as vehicles on a single track road use the centre and the wear is therefore always in the same place. Passing bays should be provided at not more than 150 yd. intervals. If the distance is greater, vehicles take a chance and run off the road which breaks down the edges. Even where the distance is less they still do it, but a ditch, large stones, or dwarf precast concrete posts at intervals alongside are a great discouragement.

The weight of traffic on a farm road is light, weight in this case being the frequency of traffic not wheel loads. A light 4-wheel lorry sometimes has a greater wheel load than a heavy vehicle with six wheels. It is speed plus weight, however, that wears out a road and the best way to cut down speed on a straight road is to construct "grips" formed with three or four rows of setts at intervals along it.

Roadways around the buildings are an important feature of the planning and vary in width according to the amount of traffic discharging on them. They should be laid clear of the buildings, except where they link them up, and set out rather on the pattern of a railway track. Large vehicles which enter a cul-de-sac must be provided with space to turn around. All bends and turning circles should be not less than 50 ft. diameter.

Internal roads serve usually to link fields together and to the buildings and take mostly tractors, trailers and stock.

Construction—To keep down the cost of making farm roads local material should be used wherever possible; chalk, quarry waste, ashes, hardcore from old buildings, flints, burnt shale, limestone chatter, are all materials which make satisfactory roads. The finished surface should then be treated with a coat of tar or bitumen to keep the water out of the subsoil.

Keeping the subsoil dry is the art of successful road-making. Never, therefore, excavate into the ground to make a road, but build it up from the ground surface. All work should

be carried out in dry weather preferably during the summer months.

The junction with the highway can be carried out in precoated stone laid on a suitable stone base. It is often possible to have this work done by a highway authority when a road-making gang are working in the area. An existing farm road can be given a wearing surface of pre-coated stone laid between 2 in. and 3 in. thick and then well rolled. The work should be completed whilst the material is warm. Alternatively, uncoated aggregate can be laid first and grouted afterwards with tar or bitumen. If the surface is good it can merely be surfaced with a coating of bitumen or tar applied through a watering can and covered over afterwards.

Wheel track roads in concrete cost almost as much as a full width road, owing to the labour required in forming the track.

All sharp bends should be constructed in concrete as the greatest amount of wear takes place on a corner.

Internal roads around the building should be constructed in concrete 4 in. thick, laid on the surface of the soil, after the vegetable material has been removed. Hardcore is neither necessary nor desirable. The concrete should be composed of 1 part cement to $2\frac{1}{2}$–3 parts sand and 4 parts aggregate graded from $1\frac{1}{2}$ in. down to $\frac{3}{16}$ in. (See Building Data.)

Reinforcement is only necessary in soil of low bearing capacity such as peat, fenland silt, etc. Expansion joints are necessary every 15 ft. length of road, and the best way of forming them is to lay the concrete in a 15 ft. length, miss out the next length, but start with the farther one, then return and fill in the one between. If this is properly carried out, expansion strips of wood or fibre boards are unnecessary. When laid the concrete should be cured as described in "Concrete." (See Building Data.)

To save expense passing bays can be constructed of hardcore; they should be 7 ft. 6 in. wide by 40 ft. long.

Internal farm roads may be made by laying 4–6 in. hard-core or pitching on top of the surface of the vegetation, after it has been well rolled. The larger stones should be laid at the side, the smaller in the centre and the surface covered with ashes. A furrow slice should be turned up along the

sides to hold it together and wet spots drained and then consolidated.

Crawler and spade lug wheel tractors should be kept off farm roads. The cloven hoof and manure whilst destructive to bituminous and tar roads will not affect concrete.

Bridges; Culverts—Where ditches have to be crossed a bridge can be formed from precast concrete pipes. (See Building Data.) The "invert" or bottom of the pipe should be laid about 6 in. above the natural bed of the ditch. Placing a pipe below the bed reduces the effective diameter of the pipe if it settles, and again when it starts to silt up, as it invariably does, thereby restricting the flow of water. Oil drums, with the ends knocked out, laid end to end, and surrounded with concrete, are an alternative to pipes.

Spans of up to 20 ft. can be effectively, and economically, bridged in pre-stressed standard type concrete beams, laid on either a mass concrete abutment, or on a suitable concrete base laid on either side of the banks.

The size and depth of the unit beams vary in size and shape with the manufacturer, but 9 in. wide by 6 in. deep is an average and they can be laid with farm labour, and are often cheaper and certainly better than railway sleepers.

Cattle Grids—The time saved in opening and shutting a farm entrance gate soon pays for a cattle grid. Siting and construction needs careful consideration otherwise an owner may find himself liable to damages in case of accident or injury, especially if there is a right of way over the road. The grid must be stock proof to contain cattle, horses and pigs; it should be at least 8 ft. 6 in. long, and for sheep 10 ft. long, the width being the width of the road.

Two types of grid are manufactured, one being a metal frame hinged in the middle in the form of an inverted V and supported by two springs attached to the top of a gate post. When a vehicle contacts the frame it flattens out and is run over, the springs returning it to the original position when the vehicle has passed over.

The other consists of V-shaped precast concrete beams set together in the form of a saw tooth on a concrete slab at ground level. This is difficult to keep clean and soon fills up with mud.

The home-made type, usually found on farms, consists of 2 in. diameter mild steel tubes at 7 in. centres, fastened to 10 in. × 5 in. railway sleepers set on edge. The two top edges of the sleepers are chamfered off with an axe and V-shaped notches cut, into which the tubes are fitted for half their diameter, the other half stands proud. Three sleepers at 12 in. centres, or 2 ft. 5 in. overall, support the tubes under each wheel and there is an additional one in the centre. The sleepers in turn are supported either by three other sleepers at right angles to them, or precast concrete blocks. The total depth of the pit over which they are laid being about 18–20 in. The bottom should not be concreted.

The grid should be fenced off along its length leaving a clearance for overhanging loads. A 15 ft. by-pass gate for farm machinery to pass through should also be provided. At least 4 ft. 6 in. should be left between the grid and the gate, or driven stock may be forced on to the grid.

Fences—Temporary movable fences consist of hurdles, woven wire, cleft chestnut, or an electrified wire. The latter is more generally used owing to its low cost and the simplicity and the ease with which it moved about. A 6 volt 20 amp. battery operating the controller will last about three weeks in continuous use. To contain adult cattle a single 14 s.w.g. wire, 2 ft. 6 in. above the ground suffices. For sows a single wire 15 in. above ground, gilts 12 in., with piglets a second wire 10 in. from the ground is also necessary. Sheep are more difficult but two wires about 15 in. and 33 in. above the ground is the most satisfactory spacing. The wires must be kept taut so that when an animal rushes the fence it passes through the hair to the skin. When a wire is near to the ground vegetation has to be cut frequently if short-circuiting is to be avoided. To save cutting, creosote poured from a watering can below the wire kills off growth. Rats can often be cleared overnight from an old barn by running two wires, one earthed and one live, along the rafters at wall plate level. The wires should be about 2 in. apart.

Permanent fencing may be of concrete, or timber posts and wire, timber posts and rail, and various types and patterns of woven wire, and rabbit fencing.

The type, spacing of rails, wires and posts usually depends on the sort of stock it is intended to contain. Reinforced precast concrete posts should be bought from a reputable firm. It is impossible to make them properly using farm labour. Corner posts and straining posts are usually 6 in. × 6 in. tapering to 4 in. × 4 in. at the top and 7 ft. 6 in. long. Intermediate posts are 5 in. × 5 in. tapering to 3 in. × 3 in. Gate posts are usually 8 in. × 8 in. × 8 ft. long. Corner posts and straining posts should be set in concrete and strutted with 4 in. × 3½ in. struts. Straining posts are spaced at 150 yd. centres and intermediate posts at 10 ft. centres. If metal spacers are used the distances may be increased to 18 ft. or 20 ft. To contain every type of stock, except perhaps for lambs and piglets, seven galvanised 10 s.w.g. wires are needed starting with the bottom one which is 4 in. above the ground. The others are spaced at 5 in., 6 in., 7 in., 8 in., 9 in. and 10 in. centres but six, or even four, wires are sufficient for some type of stock, the top wire is barbed. The wires are spaced by means of galvanised eyletted strainers and winders.

Timber posts and wire fences are constructed in a similar manner to concrete. The straining and corner posts should be 5 in. × 5 in. × 7 ft. 6 in. long and strutted, and the intermediate posts about 2 in. diameter and 8 ft. 6 in. long. The latter when sharpened and driven into the ground make a stronger job than when embedded in a hole. All softwood timber should be either pressure creosoted, or preserved by the " hot and cold " process by farm labour.

Galvanised woven wire stockproof fences in steel, or aluminum alloy, can be obtained in an infinite number of varieties in every size and are secured to timber posts at 10 ft. centres. A strand of barbed wire is usually run along the top of the posts.

Post and rail fences—5 in. × 4 in. posts at 9 ft. centres; with four 3 in. × 1¼ in. sawn rails, the first 6 in. above the ground and the remainder at 11 in., 12 in. and 12 in. centres. An intermediate 3 in. × 2 in. post is driven into the ground between the main posts.

Rabbit-proof fencing comprises 18 gauge 1¼ in. mesh fencing nailed to timber posts, the construction of which is similar to the timber post and wire fence, with the exception of the intermediate posts which may be increased in distance to

12 ft. 6 in. centres. The top of the netting is clipped to a strand of barbed wire set 3 ft. above the ground, and 6 in. above that a tripwire is stretched. The bottom 6 in. of the netting should be bent to lay flat on the ground, towards the rabbit side of the fence, on top of which turves should be laid; a further wire about 8 gauge should be set about 18 in. above the ground to support the netting in the centre.

TABLE 80: WIRE GAUGE

Gauge Number	Standard Wire Gauge	Yds. per cwt.
1	300	160
2	276	190
4	232	269
5	212	322
6	192	393
8	160	566
10	128	900

Plain galvanised wire can be bought in coils by weight. Plain aluminum alloy wire is sold in coils of 28 lb. (25 yds. to 1 lb. in 10 s.w.g. approximately).

TALBE 81: BARBED WIRE (TWO STRAND)

	Yds. per cwt.	Weight per 100 yds.	Length per mile
4 point 3 in. apart	535	21	370
4 ,, 6 in. ,,	596	20	350
2 ,, 5 in. ,,	590	19	335

There are approximately 125 staples 10 s.w.g. per lb. A standard hurdle is 3 ft × 4 ft. high by 6 ft. long.

Cleft chestnut fencing varies from 3 ft. to 6 ft. in height with pales spaced from 3 in. to 5 in.

Farm fences should be 3 ft. 6 in. to 4 ft. high.

Gates.—The standard timber five-barred gate is 10 ft. wide by 4 ft. high made up of the following members:—

Back or top rail 3 in. × 5 in. taper sawn to 3 in. × 3 in.
Rails 1 in. × 4 in. sometimes tapering to 3½ in. × 1 in.
Heel or groin 3 in. × 5 in.
Head 3 in. × 3 in. or 2½ in.
Strut or braces 1 in. × 3 in.

Rails and braces should be bolted together with galvanised bolts. The top rail, or back, and second rail from the bottom should be the only two rails morticed through the head. Oak, chestnut, and larch are most suitable.

The fittings should be well made, the top hinges should be U-shaped 2 ft. 6 in. long × 1¾ in. deep, the bottom hinge 6 in. × 1¾ in. There are a variety of fasteners and hinges, etc., on the market suitable for all types of gates and hangings. Most gates are hung ¾–1 in. off centre to ensure self closing. Implements such as combine harvesters, balers and drills need a 16 ft. wide gate opening; self propelled harvesters with a pick up reel need an 18 ft. wide gate. A single gate cannot be economically made in this width in either timber or steel. For a 16 ft. wide opening it is usual to provide two 10 ft. standard timber gates and allow them to overlap in the centre and fasten them in two places. For an 18 ft. opening a tubular steel triangular double leaf gate is the most suitable.

The provision of a hardcore or concrete apron, extending the full width of the gate and six or seven feet on either side of it, is often worth the extra expense.

POULTRY HOUSING

Poultry respond to good housing conditions in the same manner as pigs do, and being much lighter in build than a pig, simpler structures can be erected to house them. Birds kept on the outdoor systems, whether free range or confined to a fold unit which is moved daily, can be housed in movable slatted floor timber huts and arks.

The building requirements for birds kept in cages in a battery house, depends to some extent on the number of rows of double cages it is intended to provide, and whether the birds will be fed on the cafeteria principle. These two items will then decide the width of the building. The

cages may be fitted into an existing building, or a new house built to suit the cages. Good insulation and ventilation is a necessity (see Building Data). A precast concrete portal frame type, infilled with either 11 in. cavity wall, or a 7 in. cavity breeze block wall, or timber, makes a good structure. An open ridge provides the best form of ventilation, providing it is adjustable. The underside of the roof should be insulated. A 4 in. thick concrete floor on hardcore raised about 6 in. to 9 in. above the ground is an advantage. Wood framed opening hopper type windows should be provided along the side walls. They should be deep and wide enough to give equal light to the bottom as well as the top cages, as lack of light will affect egg production. Roof lights should not be employed. Electric lighting and timing switches should be provided to maintain 14 hours light a day. Water and drainage should also be laid on to the house.

Deep litter houses may be of similar construction to that described for battery houses, or an all timber type house. Timber is an ideal material for the purpose, either as an infilling between a precast concrete frame, or a complete building; it is easily worked, cheap and has good insulating properties, and a life of at least 25 years if properly preserved and constructed. Many of the timber houses on the market are insufficiently braced, and in consequence distort under wind pressure and never regain their shape. The distortion often fractures the eaves gutters and provides an entry for water into the structure.

All timber buildings should be set on a dwarf wall at least 12 in., and preferably 18 in., high above the ground. Precast concrete blocks are suitable for this purpose, because the hollows can be filled up with concrete to secure the metal bolts which hold down the timber frame. A damp course must be inserted between the sill and the dwarf wall. The bottom boards covering the sill externally should overlap the top of the dwarf wall by ½ in. and be set forward ¾ in. in front of it. The sill of the hut will not rot if constructed in this way.

The roof may be covered with boards and felt, or asbestos—the latter should be insulated. Adjustable open ridge ventilation should be provided in both cases.

The height of the eaves, for a deep litter house, need not

exceed 5 ft. Windows can be set either high or low in a wall; the ratio is about 15–20 sq. ft. of glass area per 100 sq. ft. of floor space. Roof lights are difficult to insulate and should not be used.

It is not necessary to provide a concrete floor to a deep litter house, as the litter works better off the bare earth. The floor can, however, be concreted in the interests of disease control. The floor space should be about 3 to $3\frac{1}{2}$ sq. ft. per bird, with a maximum of 250 birds. A large house should be divided up into sections to provide this number per section. Large doors should be provided at each end of the building to enable the litter to be removed mechanically.

Broiler houses are used for rearing and fattening birds up to $4\frac{1}{2}$–5 lb. live weight in 11–12 weeks, when they are killed off as table birds. The birds are densely housed on deep litter at 1 sq. ft., or a trifle less, per bird. The birds spend the whole of their short life in the broiler house into which they are brought as day-old chicks. Under such circumstances the insulation and ventilation are most important.

The type of house described for laying birds managed on the deep litter or battery system is satisfactory. The height of the walls from floor to eaves need not be higher than 4 ft. 6 in. to 5 ft. and the cubic capacity of the building should be kept as low as possible.

It is essential to secure and maintain the temperature of the house between 60° and 65° F. otherwise the birds huddle together and many are suffocated. For this reason a heating system is necessary. An industrial type electric fan and heater unit is sometimes used but more economical is a low-pressure hot water pipe run around the building. The pipe should be set a little below floor level about 18 in. or 2 ft. from the wall in a trench which should be filled up with sand and the litter spread over the top. This encourages the birds to spread out over the area warmed by the pipe, rather than start to huddle in front of a fan waiting for it to come into operation.

The heating scheme should be designed on a ring main principle, to operate by gravity, except for a very large house. A simple boiler house about 3 ft. below the ground is all that is necessary. The boiler may be either coke or oil fired.

Perches should not be installed in a broiler house as birds damage their breasts on them.

Turkeys are mostly raised on straw in well-sheltered open-fronted sheds or in verandahs. The latter should be provided with a slatted floor set 2 ft. above the ground. The height from floor to eaves need not be greater than 3 ft. 6 in. An asbestos roof and open slatted walls is all that is necessary. A verandah 18 ft. × 6 ft. should house 30 growers or, used as a breeding pen, 10 females and a male.

Deep litter, broiler and battery houses should be sited with their long axis north and south. Laying houses should be maintained at a temperature of 55–60° F. with perch spaces of 9 in. per bird. Twin bird cages, in blocks of two, for battery houses are approximately 4 ft. 6 in. wide over the feeding and water troughs; an 18 ft. wide house will accommodate two blocks and three 3 ft. gangways. In slatted floor houses 2 sq. ft. per bird should be allowed.

PIG HOUSING

To produce a suitable pig house it is necessary to consider the characteristics of the animal, the economics of management, and the English climate. The pig, being nearly hairless, feels heat and cold, draught and damp, more than other farm stock. It is also, by nature, a clean animal, and can be kept so if housed under suitable conditions and being powerfully built needs a sound structure to contain it.

Pigs may be housed and fattened in straw yards, boxes, or specialised pig houses, and porkers, and sometimes baconers, are fattened in straw yards. The building should be totally enclosed and have a south aspect. A nest of straw bales with a roof over should be built inside, under which the pigs can huddle together. The area of the yard should be reduced to about 10 sq. ft. per pig to reduce their activities.

Where existing boxes are used, a straw ceiling (see Insulation and Ventilation) should be formed about 6 ft. from the floor, or high enough for a man to work under. An area of about 3 sq. ft. per pig should be set aside for dunging and plenty of dry bedding straw for them to lie on is necessary in a cold box.

Fattening houses are of two distinct types:—(*a*) The

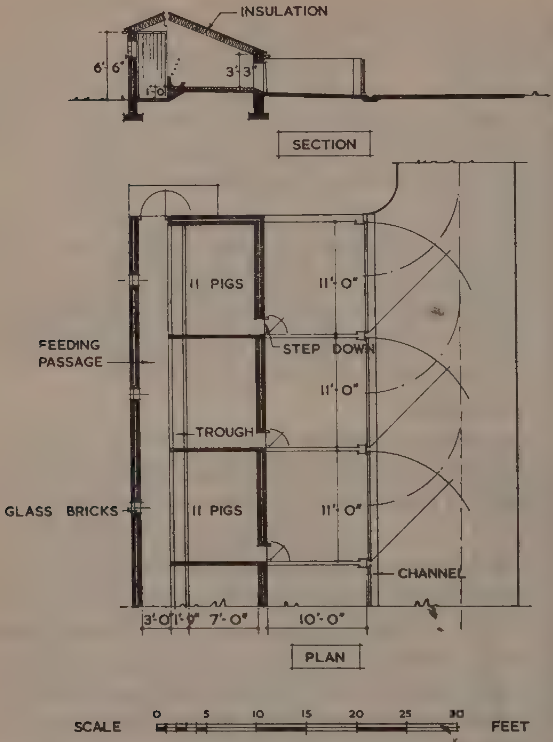

FIG. 36. Open run piggery.

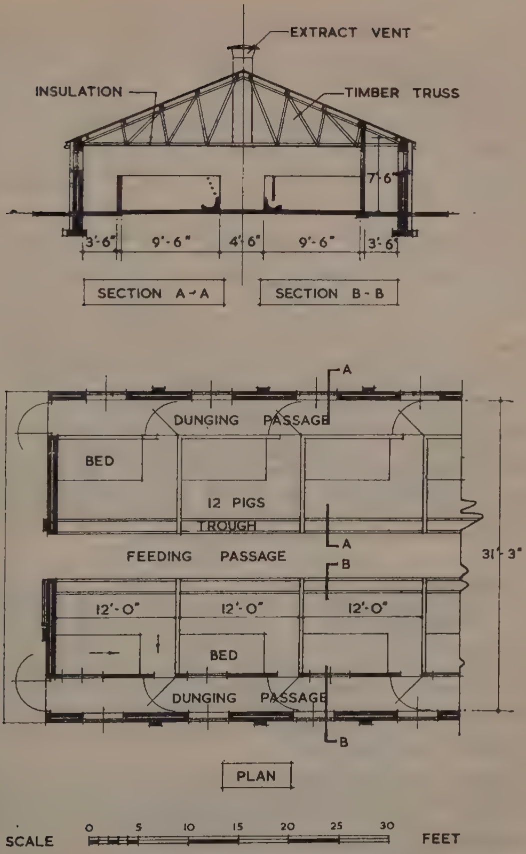

FIG. 37. Danish piggery.

indoor dunging system, such as a Scandinavian or Danish pig house, and the deep straw system. (*b*) The outdoor dunging yard system, such as the Harper Adams and McGuckian type pig house. Plans of two types are shown in Figs. 36 and 37.

There are wide variations and combinations of the two, but the distinction remains essentially the same.

The great disadvantage of the indoor dunging systems is the excessive amount of moisture produced within the building and the condensation and consequent drop in temperature which follow and also the cost of the building. Disease is also more difficult to control, or isolate, in humid conditions. It is possible to reduce the humidity by either raising the inner dunging passage wall to the underside of the roof and separate the dunging area from the main building, or design a building suitable for mechanical ventilation. Putting in an odd fan or two does not solve the problem (see Building Data, Insulation and Ventilation).

The single row out-door dunging system, in its simpler form, is the better under our climatic conditions, and the cheaper of the two to build. The upper limit is about 160–200 pigs—otherwise the building becomes unmanageably long. A double type Harper Adams or McGuckian piggery, with a central feeding passage, is not recommended because of the cross-draughts through the building.

Planning—Scandinavian type pig houses should have the longitudinal axis aligned north and south. Open dunging yards should face south to south-east. North facing yards encourage a pig to dung inside its pen. A gently sloping site can be used to an advantage with a Scandinavian piggery, as muck can be pushed out through an end door of a dunging passage into a muck-cart below, but a long piggery on a flat site should be provided with a mucking out door to every four or five pens each side.

A concrete service road should be provided to open dunging yards, otherwise it is impossible to have access for a muck-cart during winter. It is essential when straw is used in the yards and a mechanical muck fork used.

Porches are unnecessary and expensive and the cause of draught. A self-closing door and a dunging yard division

wall at least 6 in. higher than the top of the pop-hole door is better and cheaper.

For weighing, a machine may be taken to the pigs, or the pigs to a machine. The latter is probably the more convenient for an open dunging yard, and the former for the Scandinavian type. Alternatively, a small door giving access to the feeding passage from two pens is often used to get pigs out to a weighing machine but trough space is sacrificed by so doing. A better arrangement is to form a small sliding gate about 2 ft. wide by sliding smaller diameter tubes into the tubular rails over the trough and let the pigs climb out over the trough.

A food store should form an integral part of a large piggery.

Construction—Concrete blocks are unsatisfactory for the construction of piggery walls. Eleven inch brick cavity walls are very much better (see Building Data).

A Scandinavian type piggery should have the dunging passage separated from the remainder of the building by a 4½ in. thick brick division wall from floor to ceiling, which cuts off light from the windows. To overcome this defect another set of windows should be placed opposite the outer windows. Roof lights should not be employed—they are expensive and difficult to insulate and a source of condensation if not. Dunging passage walls should be rendered in cement and sand to a height of 4 ft.

The trusses should be constructed of pressure creosoted timber roofed over with asbestos sheets the underside being insulated (see Building Data) and follow the slope of the roof. An open ridge (Fig. 31) provides the best form of natural ventilation but if too high is not satisfactory. The cubic capacity of the building should be kept as low as possible and the height at eaves level need not exceed 5 ft. or 5 ft. 6 in. With a flat ceiling it must be 7 ft. The floor should be constructed of "no fines" concrete laid on an horizontal damp course and rendered in cement and sand. There should be a step down of about 2 in. to the dunging passage floor which need not be insulated.

All doors should be of the half-check type in order to produce a draught in hot weather and keep the house cool with windows timber framed, preferably long and narrow. Adjusting the ventilators on a large number of windows

from inside a building takes up a good deal of time and in consequence is seldom carried out properly. It is better to use glass brick windows and control the ventilation by means of ridge outlets.

Constructional aspects of the "Danish" type house also apply to an open dunging yard piggery, with these exceptions. The height of the wall dividing the dunging yard from the pen should be from 4 ft. 6 in. to 5 ft. 6 in. floor to wall plate, according to the type of house, and 6 ft. 6 in. or 7 ft. high to the top of the feeding passage wall. Windows or roof lights, except for a few glass bricks, or an odd window or two of the type previously described in the feeding passage walls are unnecessary. Pigs are not so active in the gloom. The step down from the pen to the dunging yard should be at least 6 in. The pop-hole door should be about 16–18 in. wide by 3 ft. high. The opening should be fitted with a self-closing door. This is preferably a side hung timber door, the top edge of which lies level with the face of the brick-work, but the bottom edge is set forward about 3 in. in front, i.e., the door when shut lies 3 in. from the perpendicular in a manner similar to air-raid shelter doors. The door is set in a timber frame on the face of the wall, but the opposite edge to the hinges overlaps the frame by 2 in. to enable a pig to get the snout behind and flick it open from outside and then slip through. From the inside the door is merely pushed open. It should not swing open more than 89° in order to be self closing.

A step at least 6 in. high is formed between dunging yard and pen and the bottom of the pop-hole door should overlap the step by at least 2 in. If the dung yard is made too large, and strawed, pigs root in it.

All yard division walls should be coped with semi-circular blue bricks, or precast concrete coping stones with a bituminous damp course underneath. Brick on edge coping, beloved by builders, is useless, as it facilitates the entry of water into the brickwork.

Troughs can be constructed of 12 in. diameter half-round glazed stoneware pipes set in concrete, the bottom being level with the floor. If the front lip is slightly undercut about 2 in., pigs get their forefeet under. Cement haunching sloped forward in front of the trough encourages them to put in their feet. The height of the trough at the front should

be about 6–7 in. The back should be 12 in. minimum. All troughs should be laid level in case whey, or wet meal, is fed at any time. Long feeding flaps bend and refuse to work after a time. It is also often difficult to force them open against ten or a dozen hungry pigs. Tubular rails, or metal protected board, set over the centre of the trough, are better.

Breeding Pens—Two alternative systems of breeding are generally practised:—(*a*) the outdoor, where sows farrow in movable huts or arks set in a field or grass ley, and (*b*) the indoor system where the sow farrows in a box or pen the litters being transferred to a yard, or fattening pen after weaning. Where piglets are weaned in 12–14 days the latter is the more convenient method.

Portable huts and arks used for outdoor farrowing should be strong and well insulated. The frame should be constructed of not less than 3 in. × 2 in. timbers, properly "framed" together and braced against lateral movements. The floor should be covered with 1 in. tongued and grooved boards. A floor area of 50–60 ft. super is suitable, or a hut size of 7 ft. × 8 ft. The pop-hole should be about 2 ft. wide by 3 ft. high set off centre. Some are fitted with a small detachable porch on the front to prevent draughts inside. It is advisable to have a creep, or nest, at the side of the hut, and a draught-proof access door at the rear to give access for the pigman without having to crawl through the pop-hole. Arks, or huts, may be collectively moved on to a large concrete standing provided for the purpose near the farm buildings during the winter the whole area being surrounded with straw bales. This makes labour conditions for feeding and watering more tolerable. Overhead lighting on poles should also be provided.

Where sows farrow in boxes the size should not be less than 8 ft. × 10 ft., giving a floor area of 80 sq. ft. A small creep, or nest, approximately 3 ft. × 5 ft. should be provided for young piglets. The entrance to this should be about 10 in. high and placed at one end. If a sow sees the piglets feeding at the trough she may try and get in, and get her head fast. Farrowing rails should be 10 in. from the wall and 10 in. above the floor, a 2 in. diameter steel tube being probably the best material to use. It should be supported

at about 4 ft. 6 in. centres along the wall, but not from the floor.

Some boxes are completely walled off from the feeding passage, a door with small inspection window being the only means of entry for the pigman. Meal is fed through a hatch in a wall. These pens are sometimes provided with an open dunging yard and are quite satisfactory when provided with the self-closing door previously described. Dung outlet holes through a wall should not be provided and all sources of floor draughts eliminated by close fitting doors, etc.

Where early weaning is practised, opportunities exist for reducing pen sizes and building costs. Pens 6 ft. 6 in. wide by 7 ft. 6 in. or 8 ft. long may be constructed opposite each other, or in single rows, across a dunging passage about 10 ft. 6 in. wide. The sow is placed in the pen a few days before she is due to farrow. At farrowing a wooden crate is brought into the pen and the sow put inside. For feeding and exercise she is brought into the passage each day and at the end of 10–14 days both the sow and the crate are removed, leaving the piglets behind where they remain until it is required again. The division wall between pens need only be 3 ft. 6 in. high and constructed of 4½ in. brickwork. The house in which the pens are provided should be well insulated.

Data—Fattening houses. The number of pigs per pen should not exceed 10 or 12, as they are more manageable and can be graded more evenly.

Trough space per fattener 12 in. long.

The temperature of a fattening house should be maintained at 60–65° F. Violent fluctuations of temperature indicate faulty ventilation or insulation, or both.

Piglets require a steady temperature of 70–75° F. and heat is required to maintain it.

Pig drinking bowls should be 7–8 in. above floor level.

Sows in milk will drink 4–5 gal. a day.

Drinking bowls should be placed in the dunging area, in open dunging yards, and should be protected against frost.

Floor area of Scandinavian type piggery, 8–10 sq. ft. per pig per pen, plus 3½ sq. ft. per pig dunging passage area.

Floor area for open dunging yard systems. Covered area 6–8 sq. ft. per pig, dunging yard 8–9 sq. ft. per pig.

The size of a farrowing crate is 7 ft. long × 2 ft. 6 in. wide × 4 ft. high. A space of 9 in. should be left between the floor of the crate and the lower rail to enable the piglets to get through.

GENERAL DATA

MATERIALS

The length of life of most building materials is determined by the resistance to frost action. In our climate with four months of the year having an intermittent cycle of rain, freeze and thaw, the conditions are particularly severe.

The art of good building is to select the right materials for the right conditions and put them together to get the right results.

TABLE 82: SAFE LOADS

Nature of Ground	Safe load in tons per sq. ft.
Natural bed of silt, peat, recent made ground	$\frac{1}{4}$
Alluvial soil, very wet sand, made ground well compacted, or tipped several years	$\frac{1}{3}$–$\frac{1}{2}$
Natural bed of soft clay, wet sand ...	1
Natural bed of fairly dry clay, fine dry sand or loam	2
Natural bed of dry, firm clay, boulder clay and gravel	3
Compact sand or gravel, hand boulder clay in deep foundation	4
Hard sandstone, limestone and chalk ...	5–10

All foundations should be excavated down to a solid bottom where the bearing capacity of the ground is over 1 and under 4 tons per sq. ft. safe load. The depth should not be less than 18 in. Excavation in clay should always be taken below the frost line.

Weight and bulk before excavation (approximately):—

Ground	Weight in tons	Cubic feet
Clay	1	20
Sand and gravel ...	1	22
Chalk	1	18
Earth	1	24

Increase in bulk of excavated material:—

Sand and gravel	$\frac{1}{10}$–$\frac{1}{8}$
Earth, loam, clay	$\frac{1}{5}$–$\frac{1}{4}$
Chalk	$\frac{1}{3}$

Concrete—Is composed of Portland cement, aggregate and sand. Aggregate may consist of crushed gravel, broken stone or brick. Sand is really another fine aggregate which fills in the voids between the cement paste and the large aggregator.

TABLE 83: CONCRETE MIXES FOR VARIOUS PURPOSES

	Cement	Sand	Aggregate
Mass concrete in foundations ...	1	3–3½	6 Graded from 1¾ in. down to ¾ in.
Concrete foundations for walls carrying heavy loads Concrete ground floors	1	2½	4 Graded from 1½ in. down to $\frac{3}{16}$ in.
Concrete roads Reinforced concrete	1	2–2½	4 Graded from ¾ in. down to $\frac{3}{16}$ in.

Aggregates described " as dug " or " all in " should not be used. Sand must be clean and sharp and free from vegetable matter, loam and clay.

Water for making concrete should never be obtained

from ditches, rivers or streams. Only clean water should be used.

To make good concrete the aggregate should contain particles ranging in size from the smallest to the largest. Mixes are generally described in terms of the proportion of cement, coarse aggregate and sand which they contain, and measured by volume. The strength of concrete depends upon the relative proportions of water and cement—the higher the proportion of water in the mix, the weaker the concrete. Insufficient water also reduces the strength of concrete. All aggregates contain water in varying amounts and a method of determining an excess of water in the mix, which is the commonest fault in concrete making, is by means of a slump test. This may be carried out in a rough and ready manner by means of a tall, but narrow, sloping sided bucket which should be filled to the top with concrete and allowed to remain for 10 or 15 seconds. A board is then placed over the top and the bucket quickly inverted and withdrawn taking care the handle does not spoil the "pie." It will then be seen the concrete has slumped down. Measure the height of the slumped concrete and compare with the internal height of the bucket. If less than three-quarters of the latter there is an excess of water in the mix.

Concrete mixing by hand should be carried out on a clean wooden platform being turned over twice dry and twice wet. A mechanical mixer makes better concrete but the mixing time must not be less than two minutes.

Concrete should be placed, and not dropped or shot into position as this causes segregation of the material. All concrete should be used within an hour of mixing.

During frosty weather, newly laid concrete must be protected with straw or old bags. All concreting should cease when the temperature falls below 40° F. In hot weather the surface of newly laid concrete should be kept damp by means of wet bags, tarpaulin or straw.

Foundations—The width of a concrete strip foundation should be about twice the thickness of the wall it supports, and about the same thickness. On soils of low bearing capacity, both dimensions may have to be increased and the concrete reinforced as well.

On fens or on made ground, reinforced concrete raft

foundations laid on top of the ground and extending well beyond the limits of the building are a necessity. Work of this kind should be undertaken by a firm of civil engineering contractors as the quality of the concrete and the positioning of the steel reinforcement is most important. The work cannot be carried out by a small local builder, or farm labour.

In shrinkable clays, foundations should be taken down to a depth of not less than 5 ft. 6 in., otherwise they fracture during a drought. To avoid the expense of deep foundation a hand operated or machine operated post hole auger, not less than 10 in. diameter and preferably 12 in. diameter, can be used for making holes 5 ft. 6 in. or 6 ft. deep at about 4 ft. 6 in. centres along the walls. The holes should be filled immediately with concrete and ordinary strip foundations laid on top about 1 ft. 6 in. to 2 ft. below ground level. The method is simple and cheap and can be readily carried out by a local builder or farm labour.

Large areas of concrete for floors, roads, cattle yards, etc., should be provided with expansion joints, at not more than 15 ft. lengths in any direction. Concrete block walls, concrete bricks, and long lengths of concrete lintel should have them also. Hardcore is only necessary underneath a concrete floor and the thickness should be not less than 4 in. A concrete floor laid on top of consolidated hardcore need not exceed 4 in. in thickness and should a heavy load be carried must be reinforced. "No fines" concrete may be made with either light-weight, or ordinary aggregate. The usual grading is $\frac{3}{4}$–$\frac{3}{8}$ in. Sand is not used. The mix is 1 cement to 8 aggregate by volume, but for light aggregates 1 : 6. A suitable and economical floor for all types of stock is 4–5 in. of hardcore, the surface of which should be levelled off with fine concrete. Then comes a layer of untearable bituminous felt or water-proofed building paper and 4 in. of "no fines" concrete. The surface should be screeded with cement and sand 1 : 2, and lightly brushed over with a stiff broom before it sets.

Portland cement is supplied in paper bags 20 to the ton. Concrete weighs approximately 150 lb. per cu. ft.

One cu. ft. of Portland cement equals 90 lb.

Precast Concrete—Agriculture is well supplied with precast concrete building products: mangers, water troughs,

fencing posts, building blocks, portal frames, pipes, pre-stressed beams and paving slabs. The concrete is made under laboratory conditions and the steel accurately placed in moulds. It is impossible for either a local builder, or farm labour, to achieve the same results.

Loft floors can be economically built in reinforced concrete or precast concrete beams or pre-stressed precast beams. The latter are often cheaper than timber for certain spans and also more hygienic.

TABLE 84: SUSPENDED REINFORCED CONCRETE FLOORS
(Cast in situ)

Slab and Reinforcement			Superimposed load in lb. per sq. ft. in addition to weight of slab										
Slab	Main Bars	Distribution Bars	6 ft.	7 ft.	8 ft.	9 ft.	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	
	in.	in.											
3 in.	$\frac{3}{8}$ @ 6	$\frac{1}{4}$ @ 9	112	73	47	30	17						lb.
4 in.	$\frac{3}{8}$ @ 4	$\frac{1}{4}$ @ 10	256	176	123	87	61	42	28	17			per
5 in.	$\frac{1}{2}$ @ $5\frac{3}{4}$	$\frac{3}{8}$ @ 16	442	308	221	162	120	89	65	47	32	20	sq.
6 in.	$\frac{1}{2}$ @ $4\frac{1}{2}$	$\frac{3}{8}$ @ 12		491	358	203	156	119	91	68	50	35	ft.

Based on ordinary grade concrete 1 : 2 : 4 mix with simply supported ends. The minimum superimposed load on a loft floor is usually about 112 lb. per ft. super but frequently 200 lb. per ft. super.

Average safe load in compression on concrete 1 : 2 : 4 mix is 10 tons per sq. ft.

TABLE 85: MANUFACTURED PRECAST CONCRETE FLOOR SLABS
(Ordinary reinforced concrete)

Width and Depth of Slab (Average)	Average Dead Weight lb. sq. ft.	Safe distributed superimposed load (in lb. per sq. ft.)				
		Up to 60	100	150	200	
		ft. in.	ft. in.	ft. in.	ft. in.	
10 in. × $4\frac{1}{2}$ in.	32	10 0	9 0	8 0	7 0	Span
10 in. × 5 in.	35	12 0	11 0	10 0	9 0	in
10 in. × 6 in.	40	14 0	13 0	12 0	10 6	feet

TABLE 86: MANUFACTURED PRECAST PRE-STRESSED CONCRETE FLOOR SLABS

Width and Depth of Slab (Average)	Average Dead Weight lb. per sq. ft.	Safe distributed superimposed load (in lb. per sq. ft.)				
		Up to 60	100	150	200	
		ft. in.	ft. in.	ft. in.	ft. in.	
10 in. × 4 in.	30	16 0	14 0	12 0	11 0	Span
10 in. × 5 in.	36	19 0	16 0	13 6	12 0	in
10 in. × 6 in.	41	21 0	18 0	15 6	14 0	feet

The above tables are for guidance only and are based on averages. For precise information consult manufacturers' lists.

TABLE 87: MATERIALS REQUIRED FOR CONCRETE SLABS

(Per 100 sq. yds. of material laid)

Mix	Material	Unit	Thickness of Slab		
			4 in.	5 in.	6 in.
1 : 2 : 4	Cement	Ton	2·73	3·40	4·00
	Sand	Cu. yd.	5·10	6·30	7·50
	Ballast	Cu. yd.	10·10	12·60	15·10
1 : 3 : 6	Cement	Ton	1·90	2·37	2·85
	Sand	Cu. yd.	5·30	6·60	8·00
	Ballast	Cu. yd.	10·50	12·00	15·70

TABLE 88: COVERING CAPACITY PER CUBIC YARD OF CONCRETE

(In sq. yds.)

Mix	Thickness of Slab		
	4 in.	5 in.	6 in.
1 : 2 : 4	9	7¼	6

DRAINS

Saltglazed stoneware pipes are made in the following diameters:—4 in., 6 in., 9 in. and 12 in. In 2 ft., 2 ft. 6 in. and 3 ft. lengths.

Stoneware pipes are made in five qualities, but for farm drainage schemes two only need be considered, "Best Quality" for connections made to the village drainage system, and "Seconds Quality" where the effluent is disposed of on the farm. "Seconds" pipes have a black tarred ring around them.

Spun concrete pipes are made in multiples of 3 in. from 6 in. diameter to 30 in. and then in multiples of 6 in. up to 72 in. diameter. Lengths vary according to diameter. Pitch fibre pipes are made in multiples of 1 in. from 2 in. to 6 in. and in 8 ft. lengths.

Drains should have a velocity of 4 ft. per second when flowing full. If the fall is too great the water runs away leaving the solids behind. Four inch and 6 in. diameter pipes usually fulfil most requirements on a farm.

TABLE 89: STONEWARE PIPES, DISCHARGE AND VELOCITY

Diameter of Drain	Area of Pipe sq. in.	Fall	Velocity in ft. per sec.	Discharge in gal. per minute half full	Area in sq. ft. which could be drained with a rainfall of 1 in. per hour
4 in.	12·56	1 in 40	3·73	61·2	14112 full bore
6 in.	28·27	1 in 60	4·00	147·0	33912 full bore
9 in.	62·60	1 in 90	4·28	356·0	82080 full bore
12 in.	113·00	1 in 120	4·50	661·0	152640 full bore

Manholes should be placed between 100 ft. and 150 ft. apart. Drains under buildings and farm roads should be surrounded in concrete.

Rain water pipes should not discharge over gulleys, except where a connection is made into a public sewer. The ends of the pipe should be connected directly into the socket of a slow bend projecting about 3 in. above the ground and the joint made in a weak lime cement, sand and mortar 1 : 1 : 10 and painted over with tar. If a sleeve is fitted over the end of the rain-water pipe, the joint can be broken, the

sleeve removed, and the drain rodded in case of a blockage. It is much cheaper to construct than providing a gulley, which soon gets blocked up with straw and litter.

Where gulleys are used they should always be circular from the outlet to the dished top. The grating on top should also be circular as they are easier to keep clean and cannot fall into the gulley when it is being brushed clean. The top of a gulley should always project at least 3 in. above ground.

TABLE 90: BRICKS

Bricks	Average Size	Weight per 1000 (in tons)
Fletton bricks	$8\frac{3}{4}$ in. $\times 4\frac{3}{16}$ in. $\times 2\frac{5}{8}$ in.	$2\frac{1}{2}$
Engineering	$8\frac{7}{8}$ in. $\times 4\frac{1}{4}$ in. $\times 3$ in.	4–$4\frac{1}{4}$

Facing bricks are usually obtainable in the same sizes as Flettons, but the thickness varies from $2\frac{1}{2}$ in. to $2\frac{5}{8}$ in. according to the demand.

In some districts brickwork is still measured by the rod, which equals 408 sq. ft. of brickwork laid one brick, or 9 in., thick.

It is now customary to measure brickwork by the square yard, or yard super: 96 Fletton bricks in 9 in. work, or one brick thick, and 16 cu. ft. of mortar produce a super yard of brickwork, or 48 Flettons in a half brick, or $4\frac{1}{2}$ in., thick wall and 75 cu. ft. of mortar.

Average Safe Load in tons per sq. ft. of Brickwork

Common brickwork in lime mortar...	2–3
Common brickwork in cement mortar	5
Engineering bricks in cement mortar	8
Blue bricks in cement mortar	12

Mortar is composed of:—

(*a*) Cement and sand 1 : 3 or 1 : 4. Is generally used for foundation work and for building free standing brick piers and grain storage bins, etc., usually with engineering, and other hard bricks.

(*b*) Hydraulic lime and sand 1 : 2½ or 1 : 3. Is seldom used now except in districts where the hydraulic lime can be obtained and is used under similar conditions as (*c*).

(*c*) Cement, fatty lime and sand 1 : 1 : 8. Is a good mortar for use with Fletton bricks, precast concrete blocks and all types of non-load bearing walls.

An excess of cement in mortar does more harm than good, as it causes shrinkage in setting.

Fatty limes and hydraulic limes can be purchased in 1 cwt. bags.

The strength of brickwork lies in flushing both horizontal vertical joints solid with mortar, a practice seldom carried out to-day, laying the indents, or frogs, uppermost, by proper bonding and by thoroughly wetting the bricks before laying.

English bond is stronger than Flemish bond, but the Flemish is more pleasing in appearance.

Only one smooth face, or fair face, can be obtained in a 9 in., or one brick thick, wall.

An 11 in. cavity wall built at two 4½ in. brick skins with a 2 in. cavity between them, has excellent insulating properties, but not a great deal of strength. It is an ideal wall for calf boxes, piggeries, general purpose boxes, broiler houses, etc.

The most suitable reinforcement for brickwork is straight steel wire. Laid in porous brickwork there is a tendency to rust and bring about a cleavage of the joint especially if the brickwork is not flushed solid with mortar and the steel incorrectly placed in the wall.

A brick wall should have its head and feet protected from damp. Two courses of blue bricks laid in cement mortar make the best damp course for a farm building. A feather edged precast concrete or stone coping, with a bitumen damp course under it makes a good top to a wall. Brick on edge is not suitable for wall copings.

Tubular steel rails built either into, or through, brickwork vertically or horizontally eventually rust and burst open the brickwork. Bull pen run walls should be built of 9 in. × 9 in. precast concrete posts at approximately 4 ft. 6 in. c.c.s. and suitably holed for steel rails, with a 9 in. thick reinforced brick dwarf wall between. The interior of all brick built

farm buildings should be whitewashed internally to seal the surface of the bricks.

A free standing brick pier should not be higher than six times its least width at the base. With adequate lateral support not more than twelve times the least width of the base with a minimum thickness of 13½ in.

Grain bins built of brickwork should be reinforced every second or third course with steel wire reinforcement.

PRECAST CONCRETE BLOCKS

Precast concrete blocks are made in a variety of dimensions the most common being 18 in. × 9 in. × 9 in. and 18 in. × 9 in. × 6 in.; these are the hollow types. In addition there are also concrete solid blocks and bricks. For farm buildings they are suitable for foundation work and for dwarf walls, supporting timber or other structures on top. In large areas they expand and contract and fracture and in addition their insulating properties are extremely poor.

TABLE 91: PRECAST CONCRETE BLOCKS

	Yds. super per ton	Blocks per yd.
18×9×9 in. two cavity hollow blocks	4	8
18×9×6 in. two cavity hollow blocks	4½	8
18×9×3 in. solid T & G ends	8	8

TIMBER

Timber is purchased quantitively by the "standard," which is 165 cu. ft.

Hardwood is sometimes bought by the cu. ft.

A cord of timber is 128 cu. ft. or 8 ft. × 4 ft. × 4 ft.

A square of timber is 100 ft. super of any given thickness.

To determine the cost of a "scantling," used in the sense of cross section, or size, of timber, the following formula can be adopted.

$$\frac{\text{depth} \times \text{breadth} \times 1{\cdot}45}{100} = \text{cost per ft. run in pence at £1 per standard.}$$

Timber should be well seasoned before it is used and for farm buildings the moisture content should be reduced to 15–16 per cent.

Stress graded timber may be obtained in various grades determined by the number of knots, lack of straightness, wavy edges and other defects.

A timber, or any other, type of beam, rigidly built into a wall is much stronger than one merely supported at the ends.

Laminated timber portal frames are manufactured in spans up to 40 ft.

Plywood can be obtained in thicknesses of $\frac{5}{16}$ in., $\frac{3}{8}$ in., $\frac{1}{2}$ in. and $\frac{5}{8}$ in., in sheets 4 ft. and 8 ft. and in various grades and qualities of timber.

The greatest enemy of timber is damp, as it provides ideal conditions for both fungoid growths and attack by wood-boring insects. The latter often gain entry into timber from the ends and especially where built into brick walls.

The ends of all structural timber should therefore be creosoted by means of the hot and cold process. Timber scantlings are immersed end-ways in a metal drum half full of creosote. Heat is applied below the drum and then removed and the creosote allowed to cool off before removing the timber. The opposite ends are then similarly treated.

Timber joist and boarded floors are expensive to construct, especially when designed for heavy superimposed loads over a wide span.

TABLE 92 : SUPERFICIAL AREA PER STANDARD

Cubic feet × ·00606 = standard

Thickness Inches	Square Yards	Square Feet	Square
$\frac{1}{2}$	440	3,960	39·6
$\frac{3}{4}$	294	2,640	26·4
1	220	1,980	19·8
$1\frac{1}{2}$	147	1,320	13·2
2	110	990	9·9
$2\frac{1}{2}$	88	792	7·9
3	78	660	6·6

TABLE 93 : TIMBER REQUIRED PER SQUARE OF FLOORING

Square edge

Width Inches	Running Feet	Superficial Feet	
3	418	105	Add 5 per cent. for cutting & waste.
5	247	103	
6	205	103	
7	175	102	

TABLE 94 : CUBIC FEET OF TIMBER IN RAFTERS AND JOISTS

Dxb in Inches	Centres			
	12 in.	14 in.	16 in.	18 in.
9 × 2	12·5	10·7	9·4	8·3
7 × 2	9·7	8·4	7·3	6·5
5 × 2	6·9	6·0	5·2	4·6
4 × 2	5·6	4·8	4·2	3·7
3 × 2	4·2	3·6	3·1	2·8

TABLE 95 : MAXIMUM SPAN OF FLOOR BOARDS

Thickness Inches	Maximum distance between centres of supports	
	T & G Boarding Inches	Plain Edge Boarding Inches
$\frac{3}{4}$	16	—
$\frac{7}{8}$	20	—
1	24	18

ROOFS

In older buildings roof coverings were supported on King Post and Queen Post roof trusses. The amount of timber used, and the cost of construction, no longer make them economical. Timber roof trusses are now made from lighter timber sections bolted together with various types of timber connectors. They can be made in spans up to 35 ft. or bought manufactured ready for erection.

Other types of roof truss are steel, or the portal frame method of roof support in either precast concrete or steel.

Table 96 gives a list of the various types of covering material and method of support.

Bituminous felt, or water-proofed paper, should not be laid under roofing material on farm buildings, with the exception of dwelling houses. The underside of either slated or tiled roofs should not be torched under any circumstances.

Asbestos sheets and fittings are obtainable in an infinite variety of standardised shapes. Slotted or perforated sheets are available and are a useful form of cover for buildings housing stock, especially cowsheds. They improve the ventilation, which in turn tends to reduce condensation. Forty per cent. slotted sheets to 60 per cent. plain is a useful combination. Asbestos sheets should have an end lap of 6 in. and a side lap of $1\frac{1}{2}$ corrugations for a $22\frac{1}{2}°$ pitch. Flatter pitches are not recommended as the life of the roof is reduced to about 20 years. It is unsafe to walk over an asbestos roof more than 10 or 12 years old. Walking boards, or roof ladders, should always be used.

Corrugated iron sheets should only be used over an open, or partly open, building such as a dutch barn, or an implement shed. Galvanised iron nails should be used for securing the sheets. End laps should not be less than 6 in. with a side lap of $1\frac{1}{2}$ in. corrugations.

Cedar shingles are obtainable in bundles of about 100. In exposed positions and for flatter pitches the battens should be set to a $3\frac{3}{4}$ in. gauge. Copper nails should be used to secure the shingles except when oak is used.

Tiles make a good roof covering for stock, but they are expensive compared with asbestos. Hand made tiles with nibs should always be re-used if in good condition. A

TABLE 96 : ROOFING MATERIAL DATA

Material	Size of Unit	Min. Pitch	Method of Support	Maximum Spacing of Supports	No. of Units Per Square	Approx. Weight Per Square
Small-section corrugated asbestos sheets (B.S.690: 1945)	4 ft. increasing by 6 in. to 10 ft. 2 ft. 6 in. wide	25°	Purlins	3 ft. centres	11–12 4–5	310 lb.
Large-section corrugated asbestos sheets (B.S.690: 1945)	4 ft. increasing by 6 in. to 10 ft. 3 ft. 6 in. wide	$22\frac{1}{2}$°	Purlins	4 ft. 6 in. centres (6 ft. vertical cladding)	7–8 3	311 lb.
Galvanised corrugated iron sheets. Eight 3 in. corrugations per sheet. Ten 3 in. corrugations per sheet. In 22, 24 and 26 gauge	4 ft. increasing by 12 in. to 10 ft. 2 ft. 2 in. wide 2 ft. 8 in. wide	$22\frac{1}{2}$°	Purlins	3–6 ft. centres according to the gauge	11–12 sheets, 8 corrugations per sheet	22 gauge $1\frac{3}{4}$ cwt. 24 gauge $1\frac{1}{2}$ cwt. 26 gauge $1\frac{1}{4}$ cwt.

Material	Size of Unit	Min. Pitch	Method of Support	Maximum Spacing of Supports	No. of Units Per Square	Approx. Weight Per Square
Cedar shingles	Length 16 in. in random widths from 4 in. to 12 in.	30° to 25°	Battens on rafters	2 × 1 in. battens at 6½ in. 5 in. and 3¾ in. gauge	According to gauge 300, 400 or 500	144 lb. at 5 in. gauge
Plain tiles in clay or precast concrete	Length 10½ in. Width 6½ in.	40°	Battens on rafters	1½ × ¾ in. battens @ 4 in. or 3½ in. gauge,	580 or 665 according to gauge	11–12 cwt.
Pantiles	Length 14 in. Width 18 in.	35°		10½ in. gauge	180	8 cwt.
Slates	24 in. × 14 in. down to 10 in. × 6 in.	30° 40°	Battens on rafters	1½ × ¾ in. battens from 10½ in. down to 4½ in. gauge	96 up to 800 according to size and lap	5·31 cwt. 10½ gauge 7·15 cwt. 3½ gauge

Material	Size of Unit	Min. Pitch	Method of Support	Maximum Spacing of Supports	No. of Units Per Square	Approx. Weight Per Square
Open boarding (Yorkshire type)	Max. length of board 18–20 ft., 6 in. wide by 1 in. thick	30°	Purlins			
Roofing felt on boards	Max. length of board 15–18 ft., 4–6 in. wide, $\frac{3}{4}$–$\frac{7}{8}$ in. thick. Felt 36 in. wide in rolls up to 425 yd. in "standard" and "heavy" weights	$22\frac{1}{2}$°	Purlins	2 ft. 6 in. to 3 ft. 6 in. according to the thickness of board		
Thatch		50°	Battens on rafters	2 × 1 in. battens from 8–10 in. gauge	11 trusses 12 in. thick 16 trusses 16 in. thick	$3\frac{1}{2}$ cwt. 12 in. thick or 11 trusses 5 cwt. 16 in. thick 16 trusses

precast concrete tile has a longer life than a poor machine made clay tile; the latter seldom reaches 20–25 years before it laminates.

Every third row of tiles should be nailed with galvanised iron nails.

Slates have the same defect as asbestos; they provide too close a roof cover which brings about condensation troubles. Where they are used they should be laid to "open" or "half slating pattern." Each slate should be nailed with two copper nails.

Open boarding, or Yorkshire type roofs, make an excellent cover for stock yards, but they are expensive. Boarding 6 in. × 1 in. is used, spaced $\frac{1}{4}$–$\frac{1}{2}$ in. apart. The two upper edges of the board are beaded, or channelled, and the underside rebated. Two or three galvanised hob nails should be driven into the purlin, under each board, to prevent moisture from condensation rotting the boards at the junction with the purlin. The boards should be well seasoned and pressure creosoted. Galvanised nails should be used.

Roofing felt on boards is usually associated with timber structures. The timber boarding should be pressure creosoted and the underside should never be underlined with vapour sealed insulating material or dry rot attacks the timber. Roofing felt should be unrolled and left on the ground for several days before use to take out the stretch. The felt may be laid horizontally, or vertically, over the ridge, with a side lap of about 2 in. according to the pitch, and 6 in. end lap.

Galvanised clout headed nails and bituminous adhesives are generally used to secure the felt to the boards.

Thatch is generally laid in bundles on fir battens, and fastened with cords and hazel rods. Straw may be either rye or wheat; barley and oat straw are inferior. Other materials are heather, rushes and reeds. Norfolk reed thatching has a life of 35 years, and rye straw 25 years. The thickness depends on the pitch, 12 in. is sufficient for a 60° pitch and 16 in. for a 50° pitch. Valleys are difficult to make watertight. With so many combine harvesters in use it is difficult to obtain long unbroken wheat or rye straw for thatching.

TABLE 97 : SPACING FACTORS FOR ROOF TIMBERS

For non-graded purlins, rafters and ceiling joists, supporting a normal roof of pantiles, slates, asbestos, etc.

Scantling Size dxb inches	Clear Span in feet										
	6	7	8	9	10	11	12	13	14	15	
3 × 2	12										Clear spacing between Scantlings in inches
4 × 2	26	18	12								
5 × 2	39	30	21	15	12						
6 × 2	62	45	34	26	21	15	12	8			
7 × 2	74	62	45	34	26	23	18	13	12	8	
8 × 2	112	74	62	45	39	30	26	21	18	13	
8 × 2½	140	92	77	56	48	37	32	26	22	16	
9 × 3		121	96	84	60	54	42	36	30		

Ridges vary in depth according to the pitch, and for normal spans and pitch are between 7 in. × 1½ in. up to 9 in. × 1½ in.

NOTE—There is a close relationship between the pitch of a roof, the lap of the units covering it, and the gauge, or spacing of the battens. A reduction in pitch must be accompanied by an increase in the lap of the unit, whether tiles or asbestos sheets, and a decrease in the gauge. Increase the pitch and the lap may be reduced, and the spacing of the battens increased.

INSULATION AND VENTILATION

There is very little accurate information available about the insulation of farm buildings, and that which is obtainable comes from studies carried out in heated buildings. There is a good deal of difference between the moist heat produced by livestock and the dry heat produced by a heating installation —a point which reduces to absurdity many of the U-values which are often put forward for farm building work.

All heavy, or dense, materials such as copper, concrete and water, etc., are good conductors of heat whilst lighter and less dense material such as fibre board, glass wool and straw, etc., are excellent insulators—so long as they remain dry. But being inherently cellular either as a mass, or in structure, they readily absorb moisture until they become

saturated, at which point they fail as insulators. Obviously it is essential to keep them dry. The usual method is to place a vapour barrier such as aluminium foil or waterproofed paper between the stock and the insulating material, but moisture is still absorbed from the atmosphere especially on damp, foggy days, and the chance of it quickly drying out again sandwiched between a vapour barrier and an asbestos roof is remote. Insulating material, therefore, to be effective should be sealed and water-tight and capable of being fastened to either a ceiling, or laid flat on top of one, without the seal being broken. At the time of writing, such a material is not being produced in this country.

Most of the heat produced inside a closed building is lost through the roof and the remainder through walls, glass windows and air leaks through badly fitting door and windows, etc. In some cases the latter can be a major source of heat loss. The amount of heat lost through a solid floor is very small indeed, the greatest amount being the ten or twelve inches of floor nearest to an outer wall.

Two hollow clay blocks laid together on edge as a lining, the top of which should be level with the concrete floor, reduces the heat loss. (See Concrete for the construction of the floor.) Placed alongside an 11 in. cavity wall it reduces the loss still further.

The most suitable type of wall construction for buildings housing stock is the cavity wall, particularly the 11 in. brick cavity wall. It has good insulating properties and animals lying against it do not become chilled. The inner brick skin remains reasonably dry, and can even be improved by whitewashing.

Solid brick walls 9 in. thick and precast concrete blocks, are not nearly so good by comparison, and when wet with rain they are often little better than an asbestos sheet from an insulation point of view.

It is difficult to satisfactorily double glaze roof lights, and it is better to omit them as they are a source of condensation if they are not insulated. A good deal of heat is lost through glass windows, and they should be reduced in area as far as possible. Glass bricks have a higher insulation value and could be more often employed in piggeries and calf pens, etc., where the amount of light needed is not very

TABLE 98 : U-VALUES FOR VARIOUS TYPES OF CONSTRUCTION

Construction	U-Values Exposure to Wind		
	Sheltered S.	Normal N.W.	Severe N.E. or N.
Roofs—			
Corrugated asbestos	1·20	1·40	1·70
Corrugated iron ...	1·25	1·50	1·80
¾ in. Boards and bitumen felt		0·50	
Tiles on battens ...	1·22	1·50	2·00
Walls—			
4½ in. Solid brickwork	0·50	0·64	0·75
9 in. Solid brickwork	0·39	0·47	0·53
11 in. Cavity wall unventilated ...	0·28	0·31	0·33
9 in. Concrete blocks	0·45	0·55	0·63
1 in. T & G boards	0·41	0·50	0·56
Floors—			
Concrete on hardcore		0·20	
No-fines concrete on hardcore		0·18	
Ventilated timber joist floor covered with boards ...		0·30	
Glass—			
Glass in metal or timber frames ...		1·13	
Glass bricks... ...		0·53	

important. Double glazed windows are expensive to construct and difficult to keep clean.

It is advisable to keep the cubic capacity of a building as low as reasonably possible, in order to keep the overall temperature of the building as high as possible.

Urine, and washing down water evaporating from the floor appreciably reduce the temperature of a building.

Metal roof trusses, purlins, water pipes and even nails used in the construction of a building having part in contact with warm air inside and part in contact with colder air outside, conduct large quantities of heat from the former to the latter.

The rate of heat loss through the construction is known as the U-value and is the measurement of the heat transmitted through 1 sq. ft. of construction from the air inside to the air outside in 1 hour when the temperature difference between the two is 1° F. A high U-value for a wall means that heat is being lost comparatively quickly through it, in other words it is a fairly good conductor whilst a low U-value means little heat is lost when it is a good insulator.

Ventilation—Good insulation makes a building " stuffy " unless ventilation is considered at the same time. It is possible to produce, and maintain automatically, constant temperature and air change within a building, irrespective of weather conditions outside, provided the building is designed for the purpose. Such a building is expensive to construct and to operate. A steady temperature can usually be maintained in a well-insulated building, except at extreme temperature ranges, providing the cubic capacity of the building is not too large. All uncontrolled air inlets, through badly fitting doors, especially sliding doors, and windows, outlets through walls, etc., should be made reasonably air-tight. The air outlet should be at the highest point of the building, preferably at the apex of the roof and fitted with some form of control (Fig. 31). Alternatively an air extractor fan or heat exchange units may be used. The latter is a fan which extracts warm moist air from inside a building and at the same time draws in fresh air from the outside by means of a duct. The warmer air transfers some of its heat to the colder incoming air and the condense which is formed is led outside the building. The unit may

be fixed either on the apex of a roof or on a side wall. Badly placed fans often do more harm than good, because when operating, air is sometimes drawn through an open window, door or a ventilator thus creating a line of draught whilst the remainder of the building remains unaffected.

At the extreme low temperature range, plenty of dry straw bedding is the best solution and the only answer to the problem, whilst well-made, well-fitting half-check doors, placed in opposite walls to induce a through draught, helps to reduce the temperature at the other end of the range.

Draughts run along walls and floors and are often deflected inside a building by cross walls and piers, etc., through badly placed pop-holes as well as under doors. It is possible to obtain wind speeds of 25 m.p.h. at floor level, and still air 3 ft. above and since stock spend most of their time on the floor general health is bound to suffer. Fig. 32 gives details of door recommended.

Buildings should be constructed as air-tight as possible and all inlets, where provided, and outlets should be controlled. Free ventilation should be provided in the roof, above the ceiling insulation, preferably through an opening in a gable end for flat ceilings. Most types of ridge ventilator only work when the wind is in a certain direction or under certain atmospheric conditions.

The choice of site is most important because buildings wrongly placed in juxtaposition to others often create wind tunnels. In addition exposed positions on hill-sides, a wrong aspect or doors placed on the " weather side " all lead to cold and draughty buildings which any amount of insulation will not remedy.

Plaster—Covering capacity for screeding.

Proportions and quantities	Thickness ½ in.	¾ in.	1 in.
	sq.yd.	sq.yd.	sq.yd.
1 bushel of cement and 1 bushel of sand	5·0	4·6	3·4
1 bushel of cement and 2 bushels of sand	6·7	5·0	3·4
1 bushel of cement and 3 bushels of sand	9·0	6·7	4·5

Granolithic screeds will not stay down unless laid on concrete which is still " green."

Walls in boxes, dairies and cowhouses, etc., are more

hygienic if white cement and light coloured sands are used in the mix, in the proportion of 1 : 3 instead of the usual cement renderings.

External rendering will not keep damp from penetrating brick walls; it often makes matters worse. Strong or "tight" cement renderings shrink or craze on setting and rain running down the face penetrates the cracks into the brickwork and dries out internally. All external renderings should be composed of 1 cement, 1 lime to 4 or 6 of sand.

Paint—The purpose of painting is to preserve and decorate. Some argue decoration is unnecessary for farm buildings, but the psychological effect of bright colours on workmen cannot be ignored even on a farm.

Painting, however, should be confined to essential features such as timber doors and frames, both wood and metal windows, steel roof trusses, purlins and stanchions, metal rain-water pipes and eaves gutters, metal and timber canopies, overhead sliding door tracks and the main farm entrance gate. All half heck doors to boxes and calf pens, chicken houses, pig arks and boarding, pop hole doors to pig pens, field gates and fencing, etc., should either be creosoted or treated with Woolman salts. Timber preserved by the latter method can be planed, sawn or worked in any way, which is impossible with creosoted timber. It also provides a good surface on which to lay a priming coat of paint.

For general purpose work lead or aluminium based oil paints are most suitable. For exterior work at least three coats must be applied on to a *dry* base.

It is advisable to whitewash the interior farm buildings every year or two since this seals the face of the brickwork, is more hygienic, and provides additional reflected light into dark corners.

Lime-whiting—One bushel of lime, 10 gal. of water and ¾ lb. tallow will cover approximately 100 yd. super, one coat; 1¾ bushels of lime, 17 gal. of water and 1¼ lb. of tallow will cover approximately 100 yd. super, two coats.

Paints—One gal.	ready mixed oil paint	weighs	26–28 lb.
" "	linseed oil	"	8¾ lb.
" "	turpentine	"	8¼ lb.

Paints cover 80–100 sq. yd. per gal. It is advisable to buy ready mixed paints in sealed tins from a reputable manufacturer.

TABLE 99 : COVERING POWER OF PAINTS AND COATINGS

	Yards super per gal.
Metalwork—	
Red lead oil paint, priming	80
first coat	100
Bitumen paint	100–125
Wrought timber—	
White lead oil paint, priming	90
first coat	110
second coat	120–130
Tar	20
Stain	100
Rough timber—	
Creosote	20
Tar	10

Glass—Flat drawn sheet glass is made in ordinary and selected glazing, the thickness being indicated by the weight per foot super.

18 oz.	24 oz.	26 oz.	32 oz.
$\frac{1}{12}$ in.	$\frac{1}{10}$ in.	$\frac{1}{8}$ in.	$\frac{5}{32}$ in.

Glass bricks can be obtained in a variety of patterns and measure $5\frac{3}{4} \times 5\frac{3}{4} \times 3\frac{7}{8}$ in. and $7\frac{3}{4} \times 7\frac{3}{4} \times 3\frac{7}{8}$ in.

Plumbing—Standard size and capacities of open top rectangular cisterns.

Dimensions ft. and in.	Length	2·0	2·0	2·3	2·5	2·6	4·0	3·10	5·0	6·0	8·0
	Width	1·5	1·6	1·8	1·10	1·11	2·0	2·11	3·9	4·0	5·0
	Height	1·5	1·7	1·8	1·10	2·0	2·0	2·11	3·0	3·4	4·0
Capacity gallons	Nominal	25	30	40	50	60	100	200	350	500	1000
	Actual to $4\frac{1}{2}$ in. average waterline	15	19	25	35	42	72	156	270	380	740

TABLE : 100 NUMBER OF BRANCH PIPES WHICH CAN BE TAKEN FROM A MAIN SUPPLY PIPE

Diameter of delivery pipe	Diameter of branch pipes				
	1½ in.	1¼ in.	1 in.	¾ in.	½ in.
	Number of branch pipes				
2 in.	2	3	6	12	22
1½ in.	1	2	3	6	16
1¼ in.		1	2	4	10
1 in.			1	2	6
¾ in.				1	3

Diameter of pipe inches	Velocity in ft. per second	Supply in gal. per minute
½	0·21	0·11
¾	0·28	0·32
1	0·34	0·69
1¼	0·39	1·24
1½	0·44	2·00
2	0·52	4·26

Cattle drinking troughs are made of galvanised iron or precast concrete. The former should be securely fixed otherwise cattle soon loosen them, especially in yards. Water supply pipes should be insulated above and below ground level. Drinking troughs in a field should have either a concrete or hardcore apron surrounding them.

Rainwater pipes should have an internal area of not less than 1 sq. in. for every 100 sq. ft. of roof surface measured on plan. The distances apart of rainwater pipes is governed by the capacity of the eaves gutters. For domestic and farm building work generally the down pipes should not exceed 40 ft. centres.

Rainwater Pipes

Diameter inches	Area inches
2	3·14
2½	4·90
3	7·00
4	12·57

Half-round Eaves Gutters

Diameter of gutter inches	Cross sectional area square inches
3	3·50
4	6·25
5	10·00
6	14·00

Gutter brackets should not be spaced at more than 3 ft. intervals.

TABLE 101: AVERAGE DAILY CONSUMPTION OF WATER OF VARIOUS TYPES OF FARM STOCK PER HEAD

Cows in milk ...	8+2 for each gallon of milk produced
Heifers in calf ...	8–10
Cattle in yards ...	10
Horse in stable ...	6–8
Horse at work ...	10
Sows in milk ...	4–5
Sheep	1
Cooling milk ...	3–6 per gal. of milk cooled, according to temperature of water
Domestic purposes ...	30 per head for all purposes

GRAIN DRYING AND STORAGE

The storage of grain is affected by its moisture content, temperature and possible pest infestation.

Moisture Content—Cereal grains respire as do other living organisms, producing heat, water and carbon dioxide, but the low level at which life is carried on in the seed form makes grain relatively stable in storage. If, however, the moisture content of the grain is too high (Table 102) this stability is affected, the mass of grain becomes subject to attack by moulds, and if sufficiently damp, by bacteria. Heat and additional moisture is produced. Grain intended for seed should be dried as soon as possible, leaving no part of it above the appropriate moisture content. Viability tends to fall off more rapidly as grain moisture content and temperature of storage is increased.

Pest Infestation—The heating of grain that is dry enough not to heat because of mould growth is usually a sign of infestation by insects or mites. The problem in this country is not so serious as in warmer climates but the precaution should be taken of storing grain away from sources of infestation, e.g., imported feeding stuffs or contaminated sacks. Weevils, mites, etc., once established in a building, can exist in crevices for considerable periods, but temperatures near freezing are fatal to all stages of the common granary weevil except the adult. These insects will not breed at temperatures below 54° F. and development is slow until 68° F. has been reached. The flour mite is particularly sensitive to humidity and cannot survive when the relative humidity in its vicinity is below 60 per cent., but above 75 per cent., its rate of multiplication becomes increasingly rapid. The characteristic smell of mites may lead to their detection but considerable populations of weevils and other insects may build up without showing on the surface of bulk grain.

Moisture Content of Grain Harvested by Combine—The moisture content of grain taken from the spout of a combine harvester is nearly always higher than that of a sample taken from the standing crop. This difference is

TABLE 102: MOISTURE CONTENT LIMITS FOR SAFE STORAGE

Materials	Type of storage	Maximum duration of storage	Maximum moisture content, per cent.
Wheat, barley, oats	bulk	2 years	12
Wheat, barley, oats	bulk or sacks	18 months	14
Wheat, oats ...	bulk	1 year	15
Barley	sacks	6 months	15
Wheat, oats ...	sacks	6 months	16
Wheat, oats ...	sacks	for early dispatch	16–18

greater when the crop contains green weeds. The moisture content of ripe grain varies from 11 to 33 per cent., but to avoid damage in threshing, cereal grains are best harvested at between 16 and 22 per cent. Below 16 special care is needed to avoid shattering the grain and above 22 to avoid bruising it. Damaged grain deteriorates in storage more rapidly than undamaged.

In trials carried out in Bedfordshire in 1948, 43·5 per cent. of combine harvested grain contained more than 20 per cent. moisture. In the same district in the exceptionally dry season of 1949 only 9 per cent. of the grain needed the same amount of drying.

METHODS OF DRYING GRAIN

Since grain rarely becomes sufficiently dry for safe storage before it is combine-harvested various methods of drying it have been evolved. All these employ the principle of forcing air of low relative humidity through the grain, which gives up its moisture to the air. The methods differ mainly in the mechanical means of presenting the grain to the air-stream and of handling it. These means govern to a large extent the air temperatures and rates of airflow which may be employed and hence the time taken to evaporate the required amount of water. The volume of air needed for the evaporation of each pound of water varies mainly

with the temperature and degree of saturation of the air leaving the drier. For this reason, driers with a working temperature of 150° F. employ between about 1000 and 2500 cu. ft. of air per lb. water evaporated, whereas driers (of the silo type) using air near atmospheric temperature require about 12,000 cu. ft. per lb. evaporated. Driers may be divided broadly into three main types: (1) batch driers in which the grain, in a static condition and contained in sacks, a tray or other compartment, or in motion in a rotating drum, is dried in separate batches in a controlled time; (2) continuous flow driers in which drying takes place as the grain passes through the machine at a controlled rate; and (3) silo driers in which grain, contained in silos in which it may afterwards remain for storage, is dried by forcing through it air at a controlled average relative humidity, the latter being chosen to be at or slightly below the equilibrium value with the desired grain moisture content.

BATCH DRIERS

Platform Driers—These, sometimes called "in-sack driers," are designed to dry grain or other seeds in light-weight hessian 2-bushel sacks. As an example, a platform drier may consist of a centrifugal fan and diesel-oil burner combined into one unit which supplies air, heated by about 25° F., to a large plenum chamber. This is usually an excavation under the grain drying floor or platform which is provided with apertures on which the sacks of grain are placed horizontally, resting on metal grids. A common size holds 40 sacks. Such a drier requires about 4 h.p. and uses 1 gal. of gas oil/hour to give an evaporation rate of about 60 lb. water/hour, equivalent to about 1 per cent. water removed per hour from the 2-ton batch. Similar driers are made in larger and smaller sizes the latter often using electricity for air heating instead of oil.

Platform driers are low in first cost and particularly suited for drying seeds without fear of mixing varieties or damage to germination. Siting should be well planned to avoid unnecessary grain handling. The amount of drying is best controlled by measuring the moisture content of the damp grain and timing the batch on the basis of the drier's known evaporation rate.

Tray driers are commonly made in sizes to hold batches of 1–3 tons at a depth of 1–2 ft. The simplest type has a fixed tray of perforated metal above a plenum chamber, and this is supplied with air by a unit similar to that used for a platform drier. The tray may be sloped to assist manual emptying or fitted with mechanical or hydraulic tipping gear.

A tray drier has the advantage of being able to accommodate any size of batch within its capacity and of being able to dry other materials besides grain. Drying control may be as described above or, where the hot air temperature is controlled by thermostat, drying may be continued until the temperature of the exhaust air has risen to a figure which previous experience has shown to be correct for the same depth of similar material.

Other types of batch drier include those in which the grain is contained between two or more vertical perforated or louvred walls and dried by horizontal air streams, those where the air is distributed throughout a static mass of grain by a multiple duct system, and drum driers. Excepting the latter, and others in which the grain is recirculated as it dries, batch driers inevitably produce grain with a moisture content gradient between the air entry and exit sides.

The objects of the vertical types are ease of filling, rapid emptying by gravity and saving of floor space. The same control methods apply.

CONTINUOUS FLOW DRIERS

The method most commonly employed is to arrange for grain to pass through the drier in one or more layers 3–6 in. thick at a controlled rate, subjecting it first to a transverse current of hot air and afterwards cooling it similarly with unheated air. To obtain maximum output driers are designed to use air at the highest temperature to which the particular type of grain can be safely exposed. All grains are very sensitive to heat, and germinative and baking qualities are easily destroyed. Table 103 gives the recommended temperature limits.

Whatever its form in detail the continuous flow drier has the following components:—(1) A tray, vertical compartment or revolving drum for containing the grain under

TABLE 103: HOT AIR TEMPERATURE LIMITS

Wheat for milling	150° F.
Barley and seed corn up to 24 per cent. moisture	120° F.
Barley and seed corn damper than 24 per cent.	110° F.
Linseed and other oily seeds	115° F.
Feeding grains for home consumption ...	180° F.

treatment. (2) A source of heat, such as an oil, gas or coke-fired furnace. (3) A fan for moving hot air through the grain. (4) A smaller fan for cooling the grain (the main fan is sometimes arranged to do both duties). (5) Temperature control gear. (6) Mechanical means for causing a steady flow of grain through the drying compartments. (7) Grain flow control gear. (8) Elevators and conveyors for the grain. (9) Reserve storage space to ensure a steady flow of damp grain to the drier.

Farm grain driers are usually rated according to their through-put when removing 6 per cent. moisture using a hot air temperature of 150° F. and since drying at this temperature takes 7–10 minutes for every per cent. removed the drying compartments usually contain about 1 ton of grain for every 1 ton/hour rated capacity.

To estimate the rate of delivery needed to obtain dried grain with a particular moisture content, the following method can be adopted.

Given (i) a drier of capacity 2 tons per hour at moisture removal of 6 per cent., hot air temperature 150° F.; (ii) a sample of grain at 24 per cent. moisture which it is desired to dry at a temperature of 120° F.

Required to find the throughput rate at which the drier must work in order to reduce the sample by 8 per cent., i.e., to achieve a final moisture content of 16 per cent.

Taking Fig. 38—A drier discharging at a rate of 40 cwt. an hour when removing 6 per cent. moisture at the standard hot air temperature of 150° F. must be set to discharge 30 cwt. an hour to remove the same amount of moisture when working at the required temperature of 120° F.

Taking Fig. 39—Given that a discharge rate of 30 cwt. per hour will remove the standard 6 per cent. moisture, this

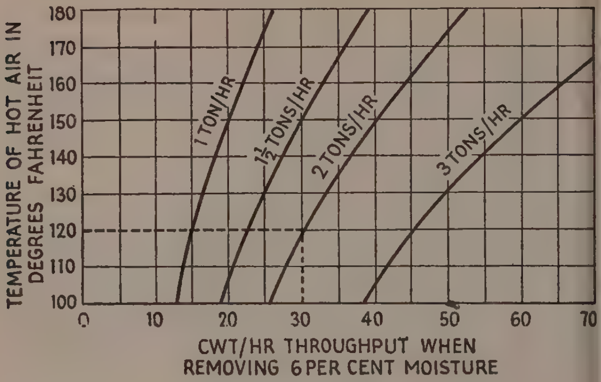

FIG. 38 (N.I.A.E.)

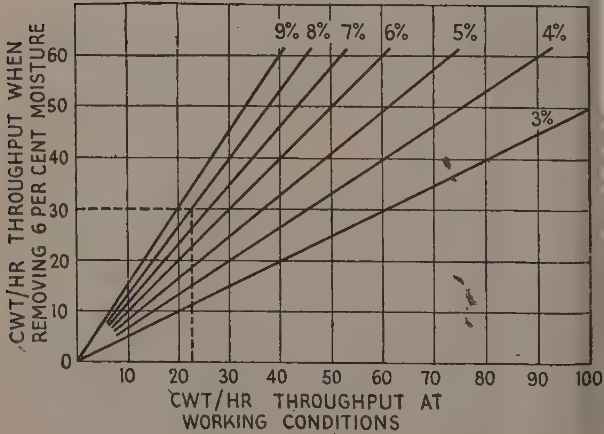

FIG. 39 (N.I.A.E.)

graph shows that a discharge rate of $22\frac{1}{2}$ cwt. an hour must be used to reduce the moisture content by 8 per cent.

A thermometer is usually fitted to show the temperature of the exhaust air near the end of the drying section.

The temperature at the end of the drying section falls when grain is reaching this point in a damper state than previously, and vice versa. It is therefore of great assistance in enabling the operator to correct the rate of grain flow to suit variations in grain moisture content, although the bulk of grain in the drier imposes an unavoidable time lag in this method of control.

When grain needs drying by more than 6 per cent. it is often advisable to dry it in two passes through the drier with a rest period of say 24 hours between, to allow redistribution of moisture in the individual grains.

Continuous flow driers are particularly useful where grain has to be dried rapidly at low running costs, but, as with other driers, care is needed to spread annual fixed costs over an appropriate annual throughput of grain.

SILO DRIERS

In situations where grain can normally be harvested at 20 per cent. moisture content or below and where storage as well as drying facilities are required grain may be dried in ventilated silos. A ventilated silo drying and storage installation consists essentially of silos or bins fitted with perforated floors or alternative air duct systems arranged to introduce air at the bases of the silos, an air heater, ventilating fan and power unit. Auxiliary equipment usually added includes a grain receiving hopper, conveyors, a grain cleaner and equipment for sacking off and weighing. Economical plants of any size can be designed. In an alternative ventilating system air is introduced through a central perforated cylinder in a cylindrical silo with perforated walls, through which the air passes after traversing the grain radially. Radially ventilated silos have been introduced to give more rapid drying, particularly in tall cylindrical silos or, alternatively, a saving in fan power.

A normal plant may have 6 or 8 silos and a fan unit capable of ventilating any 3 or 4 silos at one time at a rate of airflow capable of drying a silo in 7–10 days with con-

tinuous ventilation. Silos are connected to the ventilating system as soon as they are filled or partly filled and disconnected as soon as the grain is dry. Minimum fan capacity should be estimated from the total weight of water to be evaporated per season and the length of the harvesting season plus say 10 days, allowing 12,000 cu. ft. of air per lb of water to be evaporated. Thus, a fan delivering 6000 c.f.m. of air at 60 per cent. r.h. could be expected to evaporate at the rate of 30 lb./hour, or in the course of 8 weeks about 40,000 lb. It would thus be suitable for an annual production of 240 tons of grain at 14 per cent., drying from 20 per cent.

The drying system involves heating air by from 6 to 10° F. to condition it to an average relative humidity of 60 per cent. Since the number of silos being ventilated may also vary, a flexible air heating system is necessary. Electric heaters are convenient but should be subdivided to allow adequate control Control of air condition may be manual using a constant temperature difference between atmosphere and the heated air, with periodical checks of the resulting grain moisture content, or by automatic humidity controller. The completion of drying is judged by means of grain moisture tests.

LOSS OF WEIGHT IN DRYING

The moisture content of grain and other agricultural products is traditionally stated in terms of the weight of water in a sample as the percentage of its total weight, or on the "wet basis." It is important to avoid confusion with moisture contents expressed on the "dry basis"—the weight of water per cent. of dry matter—since, for example, 20 per cent. on the wet basis equals 25 per cent. on the dry basis.

The following formulae may be used to calculate the loss of weight during drying, the first where the weight of the dried grain is known and the second where the initial weight of the grain is known:—

$$A-B = B \times \frac{w-d}{100-w} \qquad \text{(1)}$$

$$A-B = A \times \frac{w-d}{100-d} \qquad \text{(2)}$$

where A = weight of the damper grain at moisture content w per cent.
and B = weight of the drier grain at moisture content d per cent.

Table 104 gives weights of water evaporated to leave 1 ton of grain over a considerable range of moisture content conditions.

TABLE 104: POUNDS OF WATER EVAPORATED TO LEAVE 1 TON OF GRAIN

Moisture content of grain before drying, per cent.	Moisture content of grain after drying, per cent.		
	14	16	18
16	53	—	—
18	110	55	—
20	168	112	56
22	230	172	115
24	295	236	177
26	363	303	242
28	435	374	311
30	512	448	384

DETERMINING MOISTURE CONTENT

Basic methods of measuring moisture content depend on the assumption that it is possible to remove all the water from a sample, by some process such as heating, and determine the weight of water removed. For practical purposes these methods have been modified to save time with the minimum loss of accuracy.

The method used by the N.I.A.E. for drier test work is the Carter Simon rapid oven method in which 5 gm. milled samples are dried in shallow open metal dishes at 155° C. for 15 minutes, moisture being calculated on loss of weight. Samples over 20 per cent. are predried at 80° C. for 30

minutes before milling. In another gravimetric method of similar accuracy milled samples are dried in batches in a fan-ventilated oven for 1 hour at 130° C. With both methods analytical balances are used for weighing, the samples first being cooled.

Since these methods require expensive apparatus and skilled operators they are rarely used on farms, the following being examples of those usually employed.

Infra-red Heating Method—This is gravimetric, the instrument consisting of a balance with a single pan arranged directly beneath an infra-red heating lamp. The scale of the balance is calibrated so that when the correct weight of milled grain—usually 10 gm.—is placed on the pan the pointer deflection is zero, and after the sample has been dried the pointer indicates the initial grain moisture content directly. The correct drying time—usually 20 minutes—and distance between lamp and sample are specified.

Acetylene Gas Method—This depends on the measurement of the gas evolved when powdered calcium carbide is mixed with a finely ground sample of grain of known weight. An instrument depending on this principle consists of a chamber fitted with a detachable airtight cap at one end and a calibrated pressure gauge at the other, a simple balance and a measure for carbide. After enclosing the sample and a measure of carbide the container is shaken and after a specified time the moisture content can be read on the gauge.

Electrical Methods—These methods depend on the variation of electrical resistance or impedance of a circuit with the moisture content of the grain under test. For example, in a meter using d.c. resistance as the indicator, the sample, which is milled, is compressed in a test cell containing the electrodes. The operator, after making two simple electrical adjustments by means of controls provided on the instrument, takes a dial reading and converts it to a moisture content reading by means of a calibration scale for the material under test. This takes a very short time.

Hygrometric Methods—These depend on relationships established between the moisture content of grain and the relative humidity of the intergranular atmosphere. One

instrument using this principle consists of a sensitive hair element sheathed in a perforated probe and linked to a pointer operating over a calibrated dial. Measurements are taken by inserting the probe into the grain and taking a direct reading on the scale applicable to the material concerned. Some time, up to half an hour, must be allowed to elapse before taking a reading. These instruments are usually also calibrated in relative humidity which may be of interest in itself since it largely determines the liability of grain to attack by fungi and insects.

METHODS OF STORING GRAIN

Storage in Sacks—This is usually restricted by shortage of sacks and space to put them when full, and one of the chief obstacles is that it is difficult to make a sack store vermin-proof.

Storage in Bulk—For large quantities of grain some form of bulk storage is required and the amount of handling can then be considerably reduced. Grain stored in silos should be carefully watched, and if any signs of heating occur the grain should be turned from one silo to another. Heating may occur with the rise of atmospheric temperature in spring, particularly if the grain has not been evenly dried to a moisture content of 14 per cent. Iron rods kept permanently in the bulk of grain will give a useful indication of any such rise in grain temperature. Silos can be fitted with self-emptying hoppers but this usually increases the cost by at least 10 per cent. Wheat occupies 45 cu. ft. per ton, barley 50 cu. ft. per ton and oats 66–80 cu. ft. per ton.

ADDITIONAL EQUIPMENT

In addition to a grain drier the following accessories are generally required:—

Receiving Hoppers—As the grain drier is able to work very much longer hours than the combine it is useful to have a large intake hopper so that drying can proceed when it is not possible to continue work with the combine. A large hopper is particularly necessary when handling grain in bulk rather than in sacks and if possible the hopper should

be able to hold at least 4–5 hours' output from the combine. The capacity of a hopper can be calculated as follows:—

Vertical sided part $\dfrac{\text{length} \times \text{breadth} \times \text{depth (ft.)}}{5}$ = No. of 4 bushel sacks

Sloping sided part $\dfrac{\text{length} \times \text{breadth} \times \text{depth (ft.)}}{15}$ = No. of 4 bushel sacks

The sides should slope at not less than 45°.

Cleaning Equipment—Many farm drying plants have a built-in precleaner which takes out the worst of the rubbish before the sample is dried. A final cleaning and grading is usually given in a more elaborate type of cleaner, before final sacking off for sale.

Conveyors—Where grain is handled or stored in bulk it is convenient to install a conveying system to carry grain from the receiving hopper to the sacking-off chute, passing through or by-passing as many of the intermediate stages (drier, cleaner, storage silos or bins) as is required. Bucket elevators, augers or special chain-and-flight elevators are usually employed for lifting grain, and for horizontal conveying there is a choice of belt, chain-and-flight, auger or oscillating conveyors. Pneumatic elevators may be used for combined horizontal and vertical conveying but require more power than the mechanical types.

MONTH BY MONTH ON THE FARM

JANUARY

WALK round the farm and take stock of crops, livestock and the many jobs still to be done. Sound gates easily opened, stock-proof fences and watering places easy of access and in good working order will save much wasted time in the coming months. Continue with road mending and cleaning out ditches. Exterminate rabbits and poison rats and other vermin.

Arable—Finish arrears of ploughing, cart out yard manure and when soil conditions permit carry on with the sowing of cereals. On light land barley sown now grows slowly, brairds evenly and being well-rooted can withstand drought better. It ripens more uniformly and is likely to yield malting samples. Spring sown wheat needs thicker seeding, a fine tilth and fertiliser application.

Grassland—Stone-picking, where necessary, on new leys intended for mowing saves broken knives. Matted permanent grassland requires drastic harrowing. Apply lime, phosphates and potash where required. Grassland receiving farmyard manure is best treated now. Fields to provide early bite should receive their first application of nitrogenous fertiliser with superphosphate and potash where necessary.

Livestock—Watch for symptoms of ringworm, lice and intestinal parasites. Beware mastitis and carefully note when cows and heifers are in season, for failure to mate them at the appropriate time seriously upsets herd calving plans. In-lamb ewes should be treated for worms 4–6 weeks before lambing. Clip away wool from udders and prepare the lambing pen. Provide ewes with concentrate ration or high quality silage. Breeding sows need plenty of exercise and are best running at pasture until a week before farrowing. Pig recording pays handsome dividends.

Machinery—Overhaul tractors and machinery during idle periods. In frosty weather free moving parts of drills and dung spreaders before filling. Where a farm is highly mechanised, a good workshop can save many pounds in

repairs and costly delays in the field. In the workshop it is worth while building up a set of taps and dies in various sizes. This allows one to deal with stripped threads on nuts and bolts. Studs broken off within a casting may cause stoppage of work, yet the remedy is simple with the right tools to hand. The workshop should not be open to all and sundry if order is to be maintained within, and there must be an unwritten law that all tools are replaced in their proper places.

FEBRUARY

The work of ploughing and cultivating will continue. Certain monthly routine tasks, such as arranging for calves to be earmarked by the Milk Recorder, registering heifer calves with the Breed Societies, blood testing and injecting heifers with S.19 must not be forgotten. Spring is around the corner.

Arable—Frost damage to cereal seedlings is negligible and drilling done now eases the pressure later on. As soil and weather conditions are suitable, therefore, press on with all possible drilling. Cereal-legume mixtures sown now will provide early silage. Spring beans should be sown as soil and weather conditions are favourable. Apply farmyard manure if available with 2–3 cwt. per acre superphosphate and ½–1 cwt. muriate of potash. The fertiliser application should be doubled if farmyard manure is not available. Deep sowing (3–4 in.) is essential if rook damage is to be avoided. A mixed crop of beans with a cereal often gives higher yields than these crops grown separately. The beans should be ploughed in two weeks before the cereal is drilled when the mixed crop is being grown. The inclusion of 25 per cent. early ripening barley with the cereal mixture is advantageous.

Grassland—When conditions permit continue harrowing and application of fertilisers, bearing in mind that a sequence of early " bites " should be arranged.

Livestock—All lambs should be injected with lamb dysentery serum during first 12 hours after birth. This is not necessary if lambs have gained immunity via colostrum as a result of inoculating ewes during pregnancy. On farms

where pulpy kidney is a danger a combined serum should be used. Check the amount of silage now on hand and reckon up carefully if the existing rations can be followed through until turning out time. It is important, for the best results, to make the silage last until the grass is ready. Better to reduce the amount of silage fed now than to run short later on. Examine in-lamb ewes for condition. Loss of flesh during hard weather in February predisposes to pregnancy toxaemia. Well-fed ewes produce larger lambs and suckle them better. Newly born lambs may require assistance to teat in cold weather, and may have to be confined to lambing pens for a week or two. Litters of pigs in the next two months require protection from chills, which are an important cause of anaemia, and precautions taken now to prevent draughts in the piggery may pay handsome dividends in saving lives. In lofty piggeries or where draughts are common, a ceiling of straw laid on wire netting suspended over the pig pen is cheap and simple and very efficacious. The modern tendency in pig management is to create a " fug." Milk yields tend to fall and low solids-not-fat may cause concern. Keep a close watch on the feeding. Out-wintering cattle may need additional rations.

Machinery—An in-sack grain dryer can be easily converted at a relatively low cost for grass drying. This enables a quantity of valuable, high protein food to be produced annually with the minimum of labour. Thus, when making silage an occasional load of grass can be diverted to the dryer. A small 20-sack dryer will produce about 9 tons of dried grass in an average season in this way without disorganising the normal running of the farm.

MARCH

Fields and hedgerows show signs of life and increasing activity and a " peck of March dust " is still worth a great deal in securing " timeliness " in operational work.

Arable—Press on with sowing spring corn, peas, beans, cereal-legume mixtures. Patch weak stands of winter-sown cereals and continue ploughing and cultivation for all root crops. The conservation of moisture in seedbeds is of vital importance for even germination and this applies with almost

equal importance in districts of high rainfall. The ideal seedbed for sugar beet and all small seeds is clean, level, fine and firm and with ample moisture below the top inch of soil. This means keeping cultivations to a minimum. Early sown sugar beet gives higher yields. Non-bolting varieties should be selected for the earliest sowings. Rubbed seed promotes a more regular and thinner stand and hence easier singling. Sow mangolds early; they need a long growing season and all moisture possible. Early establishment helps them to get what they require, for there is more moisture early in the season. Kale responds to liberal nitrogenous fertilising. Seeds mixtures are best sown at the same time as the nurse crop. To ensure a good "take," give a lighter seeding of cereal and be sure it is a stiff-strawed variety. If the land is dirty it may pay to defer sowing seeds mixtures until the weeds have been eradicated by spraying and harrowing.

Grassland—Check through grazing control equipment, that is, electric fences, batteries, plastic water pipes and field water troughs. Top dressing the hay ley (2–3 cwt. per acre sulphate of ammonia) is sound economics and will give increased yields of from 3 to 9 cwt. hay per acre. Roll grassland for cutting. This saves wear and tear on mower. A compound fertiliser is advisable for fields intended for repeated cutting.

Livestock—Commencing 15th March and at monthly intervals until 30th June, all cattle have to be treated in accordance with the Warble Fly Dressing Order. An approved dressing must be properly applied. In the southwest of England, because of milder climate, the warbles appear in late January to February and the dressing should be advanced accordingly. Keep a strict watch for any signs of Johne's disease which, in certain areas, appears to be increasing. The dung of infected animals is infective and the germ can live for long periods on uncultivated ground. Stagnant pools are a source of danger. Fields grazed by infected animals should not be used for this purpose for at least six months. Shelter for young lambs is of vital importance if they are to make satisfactory progress. One of the simplest ways of providing shelter at low cost and which is completely versatile is to place in the field lines of straw

bales at right angles. This enables lambs to seek shelter at all times from the prevailing wind and has proved most successful. The bales can be transferred from field to field as the flock is moved.

Poultry—Even if you hatch only a small batch of eggs, remember success depends on breeding from good stock in the finest possible condition. Great care should be taken in the selection of the eggs to be set and in managing them during incubation. The maintenance of a steady temperature in the incubator is of supreme importance. Even before this stage is reached, the results can be adversely affected if due care is not taken in collecting the eggs for hatching. For incubation always select eggs which are flawless to the eye, of good shape and texture and which weigh over 2 oz. Discard those which are very big or very small. Wipe off any mud with a damp cloth and store in racks with the small end downwards in a temperature of 50–55° F. Regular turning twice a day is very important.

General—Farm accounts now occupy much attention and valuations of crops and stock are needed to complete the year's accounts in cases where the farming year began at or about Lady Day. Clean up old mangold clamps, burn the debris and clear the site. Virus yellows in mangolds, sugar and fodder beets is spread by aphids which live in clamps during the winter and carry the disease to growing crops in the field. If mangolds must be kept for late use, keep the roots free from shoots and inspect them regularly for aphids.

APRIL

The month of blossom, cuckoos, swallows and of warm, sunny days.

Arable—On land which is "puffy" after frost, rolling is necessary before harrowing when the latter operation is contemplated as a means of weed control. Rolling should be done at a reasonable pace and with care if the seedlings are to be pressed back into the soil. After rolling wait a week or two before harrowing. Take every opportunity for cleaning land. False seedbeds encourage weed seed germination which can subsequently be killed. The best kill is

obtained when, on scraping the soil, large numbers of white thread-like shoots of germinating seeds are seen. Continue sowing beet, mangolds, kale and planting potatoes. Potato trials indicate spacing up to 21 in. in the row has resulted in no reduction in yield per acre, but higher proportion ware. Thus, quantity of seed required is reduced to 17 cwt. per acre. Heavy land to be bare fallowed should be given its first ploughing. Make sure the plough works to the full depth required and turns an unbroken furrow. This is the time when a plough pan can be eliminated without causing any ill effects to the following crop. Weeds in peas—usually the dirtiest of crops—can be controlled by using the selective herbicide D.N.B.P. Important to spray when peas are 4–10 in. in height; outside these limits spraying may damage the peas. Spraying at low volumes not recommended and coarse spray of large droplets is best.

Grassland—Are you keeping grazing records? It is not unusual to find that pastures vary within wide limits in their capacity to produce milk and meat. On recording for the first time one farmer found the production to vary from 250 cow-grazing days per acre in the worst field to as high as 420 in the best. Good grass is too precious and expensive to waste, so control the grazing. When the grazing of a field is complete, harrow to spread droppings. If they are left, the ground in the immediate vicinity will be tainted and the stock will refuse to consume the herbage, thus giving rise to patchy, coarse growth. For this reason it is often advisable to mow the second crop of grass for silage. Recent research has shown that the growth of lucerne in a grass-lucerne ley was not adversely affected by the application of 3 cwt. per acre per annum of sulphate of ammonia, which was given for three successive years. The fertiliser increased grass output without reducing the yield of lucerne. This is an important finding, since it is contrary to what many farmers believe.

Livestock—Dairy cows may be turned out to pasture. It is often advisable to feed some roughage, hay or silage each morning before they graze. This will lessen risk of digestive disorders, perhaps bloat and a reduction in butter-fat percentage of milk. When turning cows and young cattle out to pasture for the first time, watch out for grass tetany

or staggers. The daily feeding of magnesium-rich supplementary foods (calcined magnesite) helps to avoid trouble. Consult your veterinary surgeon. Prevent blackquarter by inoculation 15 days before young cattle under 2–2½ years old are turned out to grass that is suspect. Immunity diminishes with time—re-vaccinate every six months if necessary. Often advisable to first vaccinate calves at 3–4 months of age. On many farms lambs will be docked and castrated. Rubber rings can be used for both operations. Later born lambs may be done in May. Avoid excitement likely to cause bleeding if the knife has been used. It is necessary to watch out for heavily woolled sheep getting on their backs. Don't forget suckling ewes may need water, and the amount of protein in the ration can be reduced as the young spring grass comes into full growth. Keep ewes clean.

Machinery—Make sure shearing equipment is in order and the wool store is clean and ready and free from rats and mice. With certain breeds it may pay to wash sheep 7–10 days before shearing. Are you ready for the silage-making season? Silos cleaned out, molasses or meta-bisulphite ordered or in hand. Equipment overhauled, oiled and running well.

MAY

This is the month of peak pasture production. Cows should give 4–5 gallons on grass alone. It is the ideal time for making surplus grass into silage.

Arable—Make an early start singling beet—as soon as the first rough leaves appear. Each week's delay is likely to reduce the yield by ½ ton per acre. To gap until singling can be completed is better than allowing overcrowding in the row. Avoid deep inter-row cultivation late in season for this damages rooting system and reduces yield. Watch for signs of leatherjacket damage in cereals, especially on old turf. At first signs of damage, i.e., plants eaten through at ground level, use Paris green-bran poison bait or D.D.T. emulsion. Chemical weed control in cereal crops is most effective, using either contact weed killers (D.N.C., dinoseb) or growth regulator killers such as M.C.P.A. and 2,4-D. The advent of M.C.P.B. now allows safe and effective

weed control in clovers undersown in cereals or directly reseeded. Apply any time after the clovers have formed two trifoliate leaves and select a warm, dry day if possible, when there is a good prospect of dry weather to follow. Cut rye for silage before it shoots ear. When sown with ryegrass top dress immediately afterwards for second cut. Complete application of nitrogen to cereals, pull docks and thistles. Sow maize. Inter-row cultivations in root and potato crops continue.

Grassland—An application of sulphate of ammonia, 1–2 cwt. per acre, 10–14 days before cutting the hay crop, increases protein content of the hay and nitrogen not used by the plant will increase aftermath. An increase in protein content of only 1 per cent. on 100 tons of hay is equivalent to the protein obtained from 5 tons of dairy cake. Weed control in pastures is essential to secure maximum returns from milking or fattening stock. Use hormone sprays of the M.C.P.A. type for buttercups, rushes and thistles. Resistant weeds may require more than one application or strong solutions which may temporary damage the clovers. Always apply hormone sprays with the plants in full leaf and do not cut or graze for several days afterwards, to allow the weedkiller to be absorbed. There need be no fear of tainting the milk or beef from pastures so treated.

Livestock—Now is the time to crutch sheep—trimming the wool in the breech area. It is advisable to wait, particularly with ewes, until there is no risk of severe cold winds. In fat lamb producing flocks a number should be ready for sale this month. Remember to enter them in good time either to auctioneer or to F.M.C. See the sheep have water and control the grazing. All the cattle will now be lying out at night, except the calves. Keep a close watch on the udders of cows recently dried off and also on older cows which have not been seen on heat during the winter months. Served now they will calve down in February and help to maintain a level output of milk. Beware bloat or excessive scouring. Keep a constant watch in sheep for signs of foot-rot, diseased animals being a constant source of infection to healthy ones. Individual cases should be treated with sulphonamides. The flock should be walked through the foot bath (10 per cent. solution copper sulphate) every day

for a week. Heifers due to calve in the autumn should be kept on fairly poor land until after midsummer or they will become over-fat. If this happens they are then likely to go back in condition in the autumn and the milk yield will not be as high as it might have been.

General—Buildings vacated by cattle should be thoroughly cleaned and disinfected. This is particularly important when infections like ringworm have occurred during the season. Woodwork should be creosoted and blow-lamped. For walls, etc., a solution of 1 lb. washing soda in 10 gallons of water is useful.

JUNE

The main tasks are in the root crops and with the hay and silage.

Arable—Arable silage crops should be cut when the oats shoot ear. Late cutting gives more bulk but less protein and lower total nutrients per acre. A binder makes quicker and easier work possible. If the crop can be chopped this is an advantage. There is no need to use molasses. Depending on the use to which the land is to be put after arable silage there is time to sow rape or turnips which provide useful sheep meat for flushing or for dairy cows. Harrow to create a seed bed, apply small dressings of nitrogenous fertiliser and broadcast the rape at 10–12 lb. per acre. It will be ready under normal conditions in about 6–8 weeks' time. Look out for black aphis on beans, beet and mangolds. If early colonies are destroyed by fumigating with a suitable insecticide a serious attack may be averted. To control weeds in main-crop carrots, light fuel oil at rate of 20–30 gal. per acre should be used. Spray before the weeds become woody, say when carrots 1–3 in. high. If delayed, many weeds will have to be pulled by hand, which is expensive. The use of oil does not cause tainting.

Grassland—Make an early start with the hay. This means more protein. Cut when grasses first come to flower and in wet districts use tripods, tetrapods or racks. It is an advantage to make all the tripods in one corner of the field, preferably where they will be exposed to the winds. By so doing, should they have to remain out for several weeks, it

is possible to fence them off and to graze the rest of the field. Tedding after mowing speeds drying of the hay. Bracken reaches its most vulnerable state in England about now and about a fortnight later in Scotland. It is at these times that cutting and bruising should commence and a second cutting made before mid-July in England or the end of July in Scotland. Where it is possible to plough and put through an arable rotation for several years this will be found the best means of control. After mowing, meadows should receive nitrogenous fertiliser, say, sulphate of ammonia, 2 cwt., or nitro-chalk, 3 cwt. per acre, to provide abundant second cut or aftermath grazing. Pull ragwort after rain. Ragwort fed in hay may be dangerous. Bales left in the field should be placed on end or arranged in fives, thus exposing the maximum surface to the air and the minimum to rain. Generally, they should remain out for several days. If in doubt about fitness for carting, stack only in small quantities in several places rather than in large stack.

Livestock—Still maintain a careful watch for " bloat," especially in very clovery swards and on mornings of heavy dew. Where the clover content exceeds 50 per cent. of the sward it may be advisable to cut and make into silage, rather than graze. Alternatively, to cut and allow to wilt for 24–72 hours usually renders the herbage safe for feeding. During this month and July and August constant watch should be made for fly strike on the sheep and prompt attention given to any " struck." Shear sheep when weather is suitable. Fleeces must be dry. Great care must be paid to the maintenance of a clean fleece properly tied. Dirty wool, daggings and urine-stained wool should be cut off and bagged separately. When lambs are weaned, ewes should be moved to poorer pastures and lambs to clean pastures not grazed by sheep in recent weeks. It is often desirable to worm lambs at this time with phenothiazine and if they do not appear to thrive as well as they should, the treatment should be repeated a month later.

Machinery—Check the ridger mould boards, points and fin and at the same time replace, if necessary, broken tines on weeders and wearing parts on the steerage hoe. These are important matters, for failure to see they are in working order means unnecessary loss of plants or inefficient working. Either results in loss of money.

JULY

In early districts wheat harvest commences. Thunderstorms may cause badly lodged crops. The skill of the grassland enthusiast is now apparent in filling the "July gap" and preventing a fall in milk yields.

Arable—Pull early bolters in sugar beet. Turn furrow slices of bare fallow land. If seed is to be saved from potato crop it is essential to go through the crop when the plants are in flower and remove all "rogues," so maintaining the purity of the stock. At the same time remove all bolters, wildings and those dwarfed, showing leaf curl or mosaic indicating virus infection, which is transmissible through the tubers. Watch out for first signs of blight, when spraying with a suitable copper proprietary compound, preferably at high volume, is advisable. Warm, damp, "muggy" weather is particularly favourable for the disease and under such conditions it will spread with frightening rapidity unless controlled. The very first signs of blight are often found in plants growing on the old potato pies of the previous year. Inspect all such sites and destroy all plants growing there. Look out for any symptoms of potato root eelworm, the most serious pest of potatoes. Stunted plants, weak, starved appearance, with unhealthy foliage, are symptoms. Later, leaves turn yellow and brown, and plants have a "tufted head" appearance. No actual control available other than adopting sound rotation of crops. Avoid growing potatoes on same land more frequently than once in every four years. After a crop failure it may be necessary to rest land for seven or more years. Cut oats before they are dead ripe, barley when dead ripe and grain hard and skin wrinkled, and wheat when "cheesy" if a binder is used.

Grassland—Now is the time to apply further nitrogen to pastures to extend the grazing season; 2 cwt. per acre sulphate of ammonia or 3 cwt. per acre of nitro-chalk will give abundant autumn keep. Select fields well suited for late grazing, being sheltered and well drained, or a ley in its last year before being ploughed up is ideal for this purpose, for then poaching is of little moment. Summer liming is cheaper than winter applications since the subsidy from mid-May to mid-September is increased by 15 per cent.

Livestock—In July or August, depending on locality, sheep have to be dipped with an approved dip. Double dipping orders are in force in certain areas, but if D.D.T. or B.H.C. dips are used, a single dip is accepted. Do not dip on excessively sunny, hot days—it may result in sheep scald. Watch for scour in sheep which encourages maggot fly. Affected sheep should have the maggots washed from them, preferably with water. Then apply a healing dressing and not ordinary dip, which only irritates the open wound and causes more fly strike. To use arsenical dips for open wounds can easily kill the sheep. In beef and dual-purpose herds of cattle the calf subsidy can be claimed on animals 9 months of age. Check through claims on autumn-born calves. Watch for summer mastitis, especially in dry cows and heifers. Infection takes place via the teat canal and is aided by wounds or exudation from teat ends. It is a bacterial invasion which can be prevented to a certain extent by hygiene and in many cases by sealing the teats with collodion. Isolate affected animals immediately and seek professional advice. It is often a good plan to bring in all heifers and dry cows every milking to ensure inspection of the udder. Inject each quarter with penicillin and this early treatment can often save a quarter or even a life. On many farms young cattle particularly must be watched for signs of coughing which all too frequently means hoose, or husk. Graze calves and mature cattle separately, allowing calves first access and not more than 5 days on a piece. Grazing with sheep and horses is helpful. In this month and September and October, depending on when the flock is tupped, ewes may be inoculated before service with a whole culture of *Cl. welchii*, the causal organism of lamb dysentery. Repeat a week or so prior to lambing. Protective antibodies will be transmitted to lambs in colostrum. The alternative preventative is to inject anti-serum into lambs in first 12 hours after birth. Ewes should be flushed for 10–14 days before tupping by a move to good pasture, rape or mustard. They should remain on good herbage until tupping is over. Now is the time to plan for the better food to be available.

Machinery—Read combine harvester instruction book carefully to know all the adjustments for various crops and

position of all lubrication points. If grain is to be stored on the farm the moisture content should not exceed 13–14 per cent. for bulk storage and 16 per cent. in sacks. Moisture meters are essential and reasonable in price. For short periods of storage in sacks wheat can be harvested up to 22 per cent. moisture.

Poultry—Select poultry breeding stock. Birds in production now and in good hard condition should be chosen. The feather should be worn and brittle. Birds moulting before this should not be considered. All these birds should be blood tested as soon as possible for B.W.D. If more than 2 per cent. reactors important to re-test in 21 days' time.

General—At this time it is often sound business to explore the possibilities of buying forward supplies of cereals and concentrated foods for the winter. Flies are particularly bad in the cowshed this month and next and regular spraying with one of the proprietary fly-sprays incorporating D.D.T. not only adds to the comfort of the cows but also to the hygiene in the dairy. Now is a good time to limewash the dairy, again mixing in D.D.T. with the limewash.

AUGUST

Harvest in full swing in most districts. The weather forecast is an important guide to forward planning.

Arable—In most districts other than the south-west, mid-August represents the latest safe time to sow grass and clover seeds for the plants need to be well established before the danger of frost arises. Now is the time for ploughing and direct reseeding of any worthless grassland which has not already been tackled. Sow mustard or rape as catch crop for flushing ewes. On couch-infested land the use of the new herbicide T.C.A. is worth a trial. Work couch to surface and then spray, using 20 lb. T.C.A. per 100 gal. of water per acre. Leave for three weeks, work through with cultivator and repeat the dressing. Where potato tops are still green and lifting is imminent the tops should be killed by mechanical means, using a pulveriser or chemically with sulphuric acid or a proprietary compound. Early ploughing of pastures for sowing to cereals is advisable as a means of controlling frit fly and leather jackets. Carrots should be

earthed up slightly to cover the shoulder of the roots and stop them from greening, which will reduce their market value. At the same time this serves as a final check to weeds. Stubble cleaning should proceed apace to bring all weeds to surface for collecting and burning. It is simpler and cheaper to clean in this way than resort to hand weeding in the growing crop. This working of the soil encourages weed seeds to germinate and these are subsequently killed by ploughing in. If these operations are carried on until late in autumn late germinating weed seeds such as slender foxtail or blackgrass, poppy, cleavers, can be controlled. The root crop is still the pivotal crop of arable rotations and autumn cleaning eases spring work.

Grassland—Plan for good pastures for "flushing" ewes. Lucerne should be rested to ensure food reserves are built up in the root system, thus ensuring ability to over-winter. Cocksfoot leys shut up now can be consumed *in situ* by out-wintered animals. This is known as "foggage" and is a relatively old practice. Application of 3 cwt. per acre nitro-chalk provides the most economic returns of dry matter per acre. Grazing should be completed by the end of December, although on some farms January or February grazing is possible. Patch thin seeds and give an application of muck, where possible.

Livestock—Plans should be in hand for the mating season in sheep flocks. Ewes should be let down in condition now by keeping them on poorish pastures prior to being "flushed" and brought into rapidly improving condition ready for tupping. This raises fertility mainly by increasing the number of twins conceived. Careful selection of the breeding stock from high twinning families important. Select ewes born as twins and mate to rams born as twins. During this month and next on farms where liver fluke is troublesome, preventative measures should be taken. For example, by use of 1 c.c. doses of carbon tetrachloride or by hexachlorethane. On badly affected farms more than one dose may be necessary. Carbon tetrachloride may be poisonous to cake-fed sheep.

Poultry—Pullets should be in their winter quarters and receive due attention to ensure they come into production next month.

General—The new milk register received from the M.M.B. should be prepared for the commencement of the next recording year.

SEPTEMBER

The end of the corn harvest sees the start of the root harvest and another cropping year.

Arable—According to the contract with the factory, plans should be formulated to begin lifting sugar beet. Keep tops free from soil. Fresh beet tops contain oxalic acid and if fed to stock cause severe scouring. This is avoided by wilting for 10 days. An acre of tops will feed 100 sheep for a week, whilst a 10-cwt. bullock consumes about 100 lb. daily. For dairy cows the ration should not exceed 40 lb. tops, which are best fed on pasture after the morning milking. Sow rye or a mixture of rye and Italian ryegrass or rape for very early spring grazing. This can be regarded as a catch crop for after grazing down there will be time to cultivate and prepare for a root crop or even barley. Sow 1 cwt. per acre of rye with 15 lb. of ryegrass. This gives a thick, bulky crop for grazing. Carrots should be lifted and safely under cover before the danger of frost arises. Clamp in small heaps well ventilated with a straw shaft to prevent overheating. In mild districts they may be left in the ground until spring, keeping better in this way and commanding a good price. There is a risk, however, as witness the years 1939, 1940 and 1947, when many such crops were ruined. Extra nitrogen is needed when straw is ploughed in. An average crop of straw (1½ tons per acre) supplies the equivalent of ¾ cwt. sulphate of ammonia, ⅓ cwt. superphosphate and ½ cwt. muriate of potash. The bacteria and fungi which decompose it need extra nitrogen and if this is not supplied they take it from the soil and rob the following crop.

Grassland—Roughage left on pasture fields should be mown or gang mowed unless dry cows or store cattle are available to eat it off. Gang mowing helps to spread droppings and will economise therefore in chain harrowing. Pastures intended for the production of "early bite" should be shut up. You "can't have your cake and eat it." They will have been well grazed down. Follow this by a good

harrowing and rolling and the application of any basic fertilisers needed, such as lime, phosphate or potash. Any grass surplus to requirements should be ensiled. Though the quality is low in comparison with spring herbage it can be a vital foodstuff in a hard winter.

Livestock—Bring autumn calvers on to better grazing for final steaming up. Thus they get off to a good start in their milking life and this sets the pattern for the future. Milk producing tissue in the udder develops in the later stages of pregnancy and hence the need for a high plane of nutrition at that time. Where soil and climate conditions are suitable grazing kale is a cheap way of feeding dairy cows. A cow consumes about 1 cwt. in an hour, which is sufficient for maintenance and 2 gal. of milk. Normally, however, the allowance will be about half this. Fold after the morning milking. Kale gains in dry matter until November and from then on loses both bulk and quality. In folding, lay a single electrically-charged wire about 2 ft. 6in. above ground level and allow each cow about 3 yards of length. The depth of fold will vary with the quantity to be fed. See there is no danger of the wire being earthed by touching the kale. Be careful not to graze whilst crop is covered with frost. Watch out for bloat. A restricted period on the crop is advisable and hence daily moving of the electric fence is useful. Cows need as much water on kale as on grass—see they have access to adequate supplies. Check through late winter and spring born calves for those on which calf subsidy may be claimed.

Machinery—Check over corn drills and fertiliser drills with any root lifting machinery shortly to be used. A good oiling and greasing, renewal of worn parts and general adjustment is a sound precautionary task. The correct inflation of tractor tyres is far more important than car tyres. Air pressure cannot be estimated by "feel." Ascertain the correct pressure, front and rear, for make of tractor and specific conditions and then check regularly, using a pressure gauge, or have them checked by dealer. In hot weather or after hard work, there is no need to "bleed" the tyres if correct pressures are maintained.

General—Now is the time to estimate requirements for fertilisers and place the order stating when delivery will be

accepted. It is a sound policy and economical also to have the fields analysed for lime, phosphate and potash. This will be carried out free of cost by the N.A.A.S.

OCTOBER

A month of intense activity. Corn drilling proceeds apace with root lifting.

Arable—Winter beans should be sown before the end of the second week in this month. September sowings are apt to produce too much leaf liable to damage in very severe weather; November sowings are risky and when adverse weather prevents sowing now, it is better to wait until the spring and sow spring beans. Up to 30 cwt. per acre can be obtained with good management. Complete lifting potatoes. Potatoes which are to be kept until late in the season should be dusted with a proprietary hormone dust. Commence lifting mangolds. Treating winter cereals with organic-mercury dust before sowing makes for better stand and earlier growth as well as ensuring maximum yield. On wireworm infested land a combined mercury dust and soil insecticide can be used. Combined drilling of seed with phosphate reduces the quantity of fertiliser needed and gives earlier establishment of the seedlings. Apply farmyard manure for potatoes now. This eases the spring rush and the results are nearly as good as mucking in the rows. Plough dung in as soon as possible to prevent losses of plant food. To deep plough once in the rotation is advantageous and experiments have shown that increased yields of potatoes are secured by this practice.

Livestock—When assistance is necessary in calving take every possible precaution to prevent infection. Hands and arms should be thoroughly scrubbed, using carbolic soap or, if preferred, a safe disinfectant in the water. After calving, it is important to insert antiseptic pessaries into the uterus to prevent inflammation. Disinfect the navel of the calf with tincture of iodine or bluestone to prevent infection. The navel may be the seat for entry of white scour organisms. Rub the calf briskly with hay or straw and see it is housed in a warm, dry box free from draughts. In autumn sheep dipping is often advisable, particularly to destroy keds. It should be done before the first real frosts of the season are

expected and in a dry spell. In certain areas such dips have to be done before 30th November each year. On housed cattle B.H.C. and D.D.T. louse dusts and sprays used regularly during the winter prevent irritations which may result not only in unsightly patches but loss of milk yield and condition if the attack is serious and prolonged. Lowland ewes are put to ram.

Machinery—Machinery no longer needed should be checked over, oiled and greased before packing away. A coat of paint helps to preserve machinery and has a psychological effect on the operators also.

General—Stocks of winter foods on hand should be estimated both quantitatively and qualitatively. Allocation to various stock groups should be made on the basis of general rationing plans.

NOVEMBER

Working days are now very short and careful planning is needed to ensure tractors and teams and all workers can make full use of the hours of daylight and good working conditions.

Arable—Every favourable opportunity for ploughing and cultivating should be taken. Good headlamps on a tractor often enable a field to be finished after dusk, thereby saving a return journey. Potatoes should now be boxed for sprouting. Sprouting means higher yields per acre and more latitude in planting. The boxes should be stored in a light, airy shed which can be kept free from frost. Glasshouses are ideal for the purpose. They can be used for tomatoes during the summer. When the land is dry enough to carry the carts, apply lime. Ground limestone is as effective as burnt lime and much simpler to spread. Never plough lime in, always spread on the furrow.

Grassland—Apply basic slag to grassland. A dressing of 8 cwt. per acre high grade, high soluble slag is recommended every three years. Be sure to obtain an analysis of silage when commencing to feed. This can be obtained free of charge from the N.A.A.S. It enables the rations to be adjusted correctly and from the analysis much information

can be secured to allow improvement in the silage-making efforts in the coming year.

Livestock—The strongest heifers may be bulled now to calve at the end of August or beginning of September. Whilst those calving a month later will produce the greater part of their milk when prices are higher, many heifers may be missed in the colder weather of December and January. Young heifers should be yarded, well fed and bulled later. Hill ewe flocks are put to ram. The calf subsidy increases the value of well-grown calves. Don't lose it through careless rearing. Feed at regular hours, see each calf can get its own share, house in well-ventilated pens or yards and keep them growing steadily. Vaccinate with S.19 against contagious abortion at four months. Remove supplementary teats with surgical scissors in first week of life. Caustic stick and dehorning collodion should be used at 4 days. Silage should be introduced into the rations of the ewe flock about 10 weeks before lambing. It will be found that ewes fed on silage lamb down easily and milk well. They will consume from 10 to 14 lb. daily. Make sure only good quality silage is offered and this is best placed in covered racks in the field so giving some protection from the rain.

Poultry—From now on birds, especially those kept on the intensive system, should have an adequate supply of green-stuff, such as cabbage, kale or turnip tops to maintain health and egg production. Do not throw the greens on the floor amongst the litter, but suspend at a convenient height or place in a rack. The chief reasons for cracked eggs are weak or brittle shells and careless handling. Careful attention to feeding and management is essential, also make sure no thin-shelled eggs are hatched and all chicks purchased are guaranteed from strong-shelled eggs. Care taken in collection, cleaning (which should be unnecessary) and packing is well worth while.

Machinery—Don't forget the anti-freeze for your car radiator and farm tractors and engines. Draining the radiator is messy and time absorbing, but a freeze-up can be very expensive.

Change your car tyres to "town and country" and ensure trouble-free journeys in the worst weather.

General—With the advent of cold weather vermin will be seeking warmth and protection in the buildings. Wage a ceaseless war on rats which cause so much waste amongst foodstuffs. The new poison "Warfarin," which can be obtained readily, is the most effective control yet introduced. There is no danger to stock or domestic animals, yet rats devour it greedily and die. Follow the directions given for its use carefully. Taints in milk are not uncommon at this time of year and can often be traced to the foods fed. Cabbage, kale, silage and swedes should always be fed after milking and not before. Beet bye-products may produce a fishy odour. If the taint in the milk cannot be traced to one of the above causes it is likely to be a bacterial taint. In contrast to feeding taints these are always absent from the milk immediately after milking, but develop on standing. Check over the sterilisation of all equipment and the general cleanliness of the milking routine.

DECEMBER

Arable—Plan next year's cropping now. Call the staff together and discuss your plans with them. It makes them partners in the enterprise and gives added interest to their jobs. Have available past records of yields and if costings have been kept, so much the better. The best yielding crop does not necessarily leave the greatest margin of profit. The cost of securing that yield is vitally important. Examine the outfalls of pipe drainage systems after heavy rain and make sure they are functioning. Now is the time to remedy any blockage in the system due to silting up, broken tiles or the presence of roots. The best tiles are cheapest in the long run. Test each one before laying it. The cleaning out of ditches, whilst an essential operation, is very labour absorbing. Mechanical cleaners are available, a number of reasonably priced machines for carrying on the fore-end loader being available. When used in conjunction with a mechanical hedge-trimmer, the cost of this essential maintenance work can be greatly reduced. Inspect all potato and root clamps and make sure they are weatherproof, giving added protection on the windward side if doubt exists.

Grassland—In planning a sequence of grass for grazing or cutting next year, select for earliest keep either Italian or

H.1 ryegrasses to be followed by S.24 or New Zealand perennial ryegrasses. Mid-season growth comes from S.23 and Kent ryegrasses, S.26 and S.143 cocksfoot, S.53 meadow fescue, S.48, S.51 and Scotch timothy and Broad Red clover. The above sequence will be completed by securing later growth from lucerne, late-flowering red clover and white clover. Old pasture, even that containing appreciable amounts of ryegrass and white clover—which looks well—will be the latest of all.

Livestock—The quality and quantity of feed to the ewes must be improved as lambing approaches. The final 5–6 weeks of pregnancy demand a very good level of feeding. Ewes which are underfed are liable to contract pregnancy toxaemia, to drop weakly lambs and to be short of milk. Scour in calves which so often occurs in late winter is closely correlated with the standard of hygiene in the calf house. Poor liveweight gains are the direct result of an attack of scour, and routine disinfection of passage-ways and gutters, therefore, and the regular cleaning out and disinfection of the calf pens is sound management. In housed stock watch for troubles such as ringworm and lice and in cows tied in stalls for sores on legs. These are all causes of unthriftiness and can be costly if allowed to develop. Coughing in pigs, especially when they seem off colour, may indicate virus pneumonia. The disease spreads rapidly by droplet infection from affected animals. Get your vet. to treat them and if there is no sign of improvement within 48 hours it is often best to slaughter them.

Poultry—The supply of artificial lighting to laying houses in order to maintain egg production at a high level is well worth while. The number of eggs produced per hen depends upon the length of day and artificial lighting has proved equally effective to daylight for the purpose. Any pullets that have not come into production should be culled for the Christmas market. Commence cost and production records. Only by so doing can one be certain that the poultry enterprise is really efficient.

Machinery—The bulk storage of vaporising and diesel oils is worth consideration. Lower price per gallon, ease of handling in contrast to using cans and drums, less risk of fire, less wastage in filling compared with drums, and less

risk of rain or dirt getting into the fuel, constitute a formidable array of advantages. Seek advice from the oil supplier on the question of a suitable storage tank. It should hold a month's supply at the busy season, plus a reserve in case of delayed deliveries. The site must be easily accessible to the tankers and the tractors and away from buildings or stacks. Remember diesel oil attacks zinc and the tank must be of "black iron."

General—Inspect all water troughs and exposed water pipes and see they are well lagged. Time, money and great inconvenience can be saved by this simple precaution. Don't forget the farmhouse when taking these precautionary measures. During this month it is wise to check carefully through supplies of winter food remaining for each group of livestock. Bear in mind that spring may be late and turning-out time delayed. Err, therefore, on the side of caution.

FARM ACCOUNTS

THE primary purpose of farm book-keeping is to record all the cash transactions and the increase or decrease in stocks of the business at different periods. In simple book-keeping the final result is a figure of profit or loss calculated for the farm as a whole. In more advanced forms of accounting the result may be figures of costs of production and profits for each separate enterprise or product on the farm. Here only the simplest form of book-keeping which can be carried out with the minimum of trouble by the individual farmer is described.

FORM OF ACCOUNTS

Commencement of Accounts—As a rule a Trading Account and Balance Sheet are prepared from the records of farm transactions at the end of each year. The year can close at any suitable date. Often the year agrees with the term dates applicable to the country. For example, a suitable period in England would be the year ending in September and in Scotland the year ending in May, or the date may be arranged according to the date of entry to the farm. It is suggested that the autumn term is often the most suitable because by that time the crops have been harvested and there are few cultivations, so that the preparation of the Inventory and Valuation is somewhat easier.

The books required for keeping the records are two, namely, Cash Book, and Record of the Annual Inventory and Valuation.

Cash Book—Farmers are advised to keep a cash book incorporating a single cash column and the analysis of expenditure and receipts under the different headings should be undertaken as a separate operation at the end of the year. Few cash analysis books provide sufficient columns for the detailed analysis which is desirable if use is to be made of the accounts for management as well as tax purposes.

The left-hand page of the Cash Book is used for Receipts and the right for Expenditure. The Cash Book is simple to keep. Entries are shown in the example to make clear how

CASH

RECEIPTS

Date	Particulars	£	s.	d.
1.4.55	Cash—in hand	46	10	0
1.4.55	in Bank	366	10	6
6.4.55	Bacon Curers Ltd.—5 bacon pigs ...	95	0	0
8.4.55	Packing Station—20 doz. eggs	3	10	0
13.4.55	M.M. Board—March milk	210	0	0
14.4.55	Half-year dividends on "X" shares (Private)	15	0	0
15.4.55	J. Brown, Auctioneers—1 cow, barren ...	48	0	0
	2 bull calves ...	14	0	0
20.4.55	Ministry of Agriculture—Ploughing Grant	15	0	0
21.4.55	Sawmills Ltd.—Timber	18	0	0
22.4.55	Ministry of Agriculture—			
	Calf subsidy	7	10	0
	Fertiliser subsidy	16	10	0
25.4.55	T. Smith, butcher—12 culled hens ...	4	16	0
	etc.			
	etc.			
	Total	£5288	7	5

BOOK

PAYMENTS

Date	Particulars	£	s.	d.
5.4.55	Shell—Tractor Fuel	16	5	6
8.4.55	Wages	17	10	0
9.4.55	Farmers' Co-operative Society £105—			
	Feeding Stuffs	70	0	0
	Fertilisers	35	0	0
13.4.55	Rent—half-year	87	10	0
15.4.55	A.I. Centre—Service Fees	3	3	0
16.4.55	Cheque—Self	20	0	0
	etc.			
	etc.			
31.4.56	Cash—in hand	36	7	6
	in Bank	366	19	4
	Total	£5288	7	5

it should be written up. It must contain a record of all moneys received and all moneys paid out, whether or not these represent farm or private transactions, cash payments or payments by cheque. It should be written up regularly; probably at not less than weekly intervals.

In the case of small transactions which occur on a farm at irregular intervals, a note should be kept in a small note book and they should be entered in the Cash Book in one sum at the end of each month as " Sundry Expenses."

Contra Accounts—Frequently transactions are settled by contra in cases where a farmer may owe money to a supplier who, in turn, owes money for goods supplied to him. For example, John Brown, the butcher, owes the farmer £15 10s. for a pork pig and the farmer owes the butcher, J. Brown, £3 for meat. The entry should be recorded as follows:—

On the Receipts side of the Cash Book:—
J. Brown—1 pork pig £15 10 0

On the Payments side of the Cash Book:—
J. Brown—Butcher—private... ... £3 0 0

Perhaps only the sum of £12 10s. would change hands, but the transaction must be recorded in full.

Full details of the nature of each transaction must be given. The absence of details makes it difficult to prepare a correct analysis and statement of accounts at the end of the year. Moreover, the Inland Revenue scrutinise accounts carefully, and frequently questions arise concerning obscure items such as Repairs, Renewals and Sundry Expenses. These can only be answered if the full details appear in the Cash Book. Numbers and descriptions of livestock bought and sold, particulars of implements sold or acquired and quantities of goods such as feed and fertilisers should all be noted in the details column.

Accounts Payable—When goods are delivered by a supplier they are usually accompanied by an invoice giving details and the value. Subsequently an account is rendered by the supplier which may embrace a number of invoices bringing out a monthly or period total for payment. Care should be taken to handle these documents in the following

way:—Invoices sent by a supplier should be kept on a two-pin file which can be obtained from any stationer, and the file marked " Unpaid Accounts." These invoices should be kept in alphabetical order, each firm's invoices being together. When an account is rendered the invoices should be taken off this file, attached to the account rendered and the firm paid. This document now becomes a receipt and this receipt should be placed on another two-pin file marked " Accounts Paid." In this file the account should appear in the order of entry in the Cash Book, i.e., date order. By following this system it is easy at any time to ascertain Accounts due and unpaid.

Accounts Receivable—These are usually fewer in number because, as a rule, a farmer's produce is sold in large quantities and there is not a large number of small sales.

Accordingly, a record of all goods sold and not paid for can be kept in a small notebook. When the cash is received the items are marked off and the amount entered in the Cash Book at the time they occur and this is the only record made, the sale note of the Mart or other statement of the transaction, such as a packing station voucher, being kept separately in order to explain the item itself.

Annual Inventory—This is important. An Inventory must be made each year of all livestock, grain, feed, fertilisers, cultivations, loose tools and implements on the farm. The first Inventory is at Ingoing and this can be compiled readily from the documents prepared at the time of Ingoing showing the stock taken over and paid for. If there is no Ingoing cost, then there is no Inventory at the beginning and all purchases being made during the year to stock the farm are recorded in the Cash Book in the usual manner. An Inventory, however, must be made at the date fixed, as suggested, as being most suitable to complete the farm year. It consists of three sections:—

1 Stock on hand

2 Accounts due to the farm

3. Accounts due by the farm.

On taking the first Inventory, the following information should be recorded:—

1. *Stock on hand*—(*a*) Livestock—distinguishing between the various classes and showing the values in each case.

(*b*) Grain, feeding stuffs, sundry stores, and cultivations.

(*c*) Loose plant: These need not be listed but a careful estimate should be made of their value and only the total stated in the Inventory.

(*d*) Implements—This list covers all the implements on the farm, with a description of each and registration numbers where these apply, and it should state, if possible, when the implement was bought and its cost at date of purchase. If the latter figure is not known, the estimated value at the date of stocktaking should be shown opposite each item. (*Note.*—Loose plant and Implements only require to be recorded once, either in the opening Inventory or, where this does not apply, the first Inventory made at the end of the first farming year. They do not require to be taken annually.)

2. *Accounts due to the Farm*—These can be ascertained from the notebook already referred to and should include any sums which may be due for subsidies, grants, etc.

3. *Accounts due by the Farm*—A list of these is taken from the "Unpaid Accounts" file.

Examples used in Accounts (being the Opening and the Closing Inventories showing the classes of stock on hand, the accounts owing by the farm and the accounts owing to the farm):—

OPENING AND CLOSING INVENTORIES

INVENTORY AS AT 31ST MARCH, 1955

LIVESTOCK		
CATTLE	£	£
21 Cows at £50	1050	
5 In-calf heifers at £55	275	
6 1–2-year-olds at £45	270	
4 6–12-months-old at £25	100	
5 Calves at £10	50	
1 Bull	100	
	——	1845
PIGS		
5 Sows at £20	100	
39 Pigs under 3 months at £9	351	
	——	451
POULTRY		
50 Hens over 6 months at 10s.	25	
100 Pullets under 6 months at 6s.	30	
	——	55

CROPS AND STORES IN HAND		
1½ tons mixed corn	38	
1½ tons straw at £6	9	
7 tons hay at £11	77	
25 tons roots at £2	50	
18 cwt. feeding stuffs	32	
Seeds	12	
Miscellaneous stores	15	
Fertilisers	45	
	—	278
CULTIVATIONS		
7 acres mixed corn at £12	84	
6 acres kale at £5	30	
3 acres roots at £5	15	
54 acres temp. and perm. pasture at £4	216	
	—	345
		2974
MACHINERY		1450
SUNDRY CREDITORS		
Merchant—Feeding stuffs	65	
Fertilisers	42	
	—	107
SUNDRY DEBTORS		
M.M.B. March milk	210	
Bacon Factory Pigs	95	
	—	305

INVENTORY AS AT 31ST MARCH, 1956

LIVESTOCK		
Cattle		
22 Cows at £50	1100	
4 In-calf heifers at £55	220	
5 1–2-year-olds at £45	225	
6 6–12-months-old at £25	150	
8 Calves at £10	80	
1 Bull	100	
	—	1875
Pigs		
10 Sows at £20	200	
85 Pigs over 3 months at £8	680	
10 Pigs under 3 months at £5	50	
	—	930
Poultry		
50 Hens at 10s.	25	
100 Pullets under 6 months at 6s.	30	
	—	55

CROPS AND STORES IN HAND		
1 ton mixed corn at £24	24	
4 tons straw at £6	24	
6 tons hay at £8	48	
20 tons roots at £2	40	
Feeding stuffs	30	
Seeds	12	
Fertilisers	26	
Miscellaneous	15	
	—	219
CULTIVATIONS		
4 acres mixed corn at £12	48	
3 acres roots at £5	15	
7 acres kale at £5	35	
56 acres perm. and temp. grass at £4	224	
	—	322
		3401

SUNDRY CREDITORS		
Feeding stuffs	45	
Fertilisers	36	
	—	81
SUNDRY DEBTORS		
M.M.B.—March milk	198	
Bacon Factory—Pigs	108	
	—	306

How to Value Stock—The Inventory should be made on the last day of the farming year when the stock on hand is recorded and classified under the appropriate headings as shown above. The principle followed in putting a money value on the various articles is to take as a basis the cost or market price, whichever is the lower. In the case of purchased goods the cost is known, but in the case of goods produced on the farm the cost is not so easy to estimate There may be numbers of home bred livestock, home produced grain and feeding stuffs, and, in particular, cultivations, i.e., crops in the process of growing and not yet harvested. So far as possible a close estimate should be made of the cost, but in case of any difficulty it is reasonable to include produce at market value less 25 per cent. The following extract from the document covering the arrangement agreed between the Inland Revenue and the Farmers' Unions is of interest:—

> " In the case of livestock bred on the farm, if it is not possible to ascertain actual cost, no objection will be raised (by the Inland Revenue Department) to the acceptance of, as cost valuation, market price less 15 per cent. (this is now 25 per cent.), this basis, however, to apply both for the opening and closing of the year of account by reference to the market price at the opening and closing dates respectively."

In the case of purchased animals, the cost price should be the price paid with some additional figure to cover the estimated cost of the keep of the animal on the farm from the date of purchase to the date of the Inventory.

This additional cost, however, only applies to the case of immature animals. In the case of breeding stock or productive stock such as cows, ewes and sows it is better to keep them at a constant value from year to year in order to avoid paper profits.

Bank Account—This if used properly by the farmer helps greatly in preparing the Annual Accounts. As many accounts as possible should be paid by cheque and if cash is required to meet farm expenses a round figure of, say, £10 should be drawn from the bank for this purpose. When this money is spent it should be recorded as already explained. When cash for personal purposes is required, a round figure, say £20, should be drawn and entered in the Cash Book as " Personal Drawings, £20." Any household accounts, however, such as grocer, butcher, tailor, etc., paid out of the farm Bank Account by cheque should be entered under the name of the person to whom the sum has been paid and the word " Private " added.

If an account is rendered by a supplier such as, for example:

Feed & Fertilisers Ltd. £105 0 0

which covers feeding stuffs £70, and manures £35, the account should be analysed at the time of payment. This enables the account to be allocated to its appropriate columns in the end-of-year analysis. Care should be taken to enter on the cheque counterfoil the name of the person to whom payable and the nature of the payment, whether for feeding stuffs, cattle, etc.

A " Pay-in Slip Book " should be obtained from the bank

in which to record all moneys paid in. These sums should agree with the entries in the Cash Book and will form a further check. All cheques received at the farm should be lodged in the bank with other receipts after recording the details on the Pay-in Slip counterfoil. Many farmers pay a cheque or cheques into the bank only to a certain amount, obtaining cash for the balance. This is a bad practice and leads to confusion at the end of the year. Lodge all cash received in the bank without deduction and make as many payments by cheque as possible. Wages may be an exception to the latter rule.

Wages—It is desirable to have a Wages Book in which to record the name of the employee, the nature of the work, the date when employment commenced and the wage. Information concerning P.A.Y.E. is best obtained from the Inland Revenue offices. If there are several employees and the wages are paid weekly a Wages Book should be kept and the weekly wages recorded therein, the total only being entered in the Cash Book.

Checking the Cash Book—The accuracy of the Cash Book should be checked at frequent intervals and certainly at the end of the year, before proceeding to prepare the Trading and Profit and Loss Account by reconciling the entries with the Cash in Hand and at the Bank. The Reconciliation Statement at the end of the year would appear as follows.

CASH RECONCILIATION

	£	s.	d.		£	s.	d.
Cash in Hand 1.4.55	46	10	0	Total Payments ...	4885	0	7
at Bank 1.4.55	366	10	6	Cash in Hand 31.3.56	36	7	6
Total Receipts ...	4875	6	11	at Bank 31.3.56	366	19	4
	£5288	7	5		£5288	7	5

If the two sides of this statement do not coincide (after taking into account Bank Charges which may not have appeared in the Cash Book) then there must be an error in the Cash Book entries or in counting the cash in hand. The entries must be rechecked and the cash recounted and the error rectified before going on to the next stage.

Preparation of Trading and Profit and Loss Account—When the Cash Book is checked in this way it may be analysed in detail in order to bring together all like items of expenditure and receipts and to separate farm from private expenditure and receipts. For this purpose loose sheets of multi-columned cash analysis paper should be obtained and each column given an appropriate heading. The number of headings used varies according to the amount of detail required in the Trading and Profit and Loss Statement to be prepared. To complete the analysis it is necessary to take each item of expenditure and receipt in the Cash Book and to allocate it to its appropriate column.

At this stage also it is necessary to adjust for debts owing to and by the farm at the beginning and end of the year in order to attribute to the year in question only the expenditure and receipts of that year.

The Cash Analysis sheets and the debtors and creditors adjustment are illustrated between pages 704 and 705.

Cash expenditure and cash receipts of a private kind are analysed separately and will not be transferred to the farm trading account. In addition, however, to cash transactions of a private kind there may be a number of non-cash benefits which ought to be taken into account and entered on the receipt side of the account. Amongst such items would be:

(*a*) The value of the farm-house as a private dwelling.

(*b*) The value of farm stores (coal, oil, etc.) used in the farm-house.

(*c*) The value of farm produce consumed in the house.

When the value of these items has been assessed, then all the details necessary for the preparation of the Trading and Profit and Loss Statement are available. This statement would appear as is shown on pages 696 and 697.

There is no need to make a complete Inventory of Machinery and Plant each year. To the original Inventory any machinery purchased during the year should be added or any machinery sold or scrapped deducted. Then the farmer can for the purpose of determining profit for his own purposes calculate on each class of implement and machine the appropriate rate of depreciation, to allow for the annual wear and tear. Such an allowance is admitted by the Inland Revenue but here it is not intended to deal with Income Tax allowances since these fluctuate from year to

TRADING AND PROFIT AND LOSS ACCOUNT

	£	s.	d.	£	s.	d.
STOCK ON HAND ON 1ST APRIL, 1955						
Livestock—Cattle	1845	0	0			
,, Pigs	451	0	0			
,, Poultry	55	0	0			
Crops and Stores	278	0	0			
Cultivations	345	0	0			
Machinery	1450	0	0			
				4424	0	0
Purchases						
Livestock—Pigs, 2 gilts	55	0	0			
Poultry, 100 pullets ...	22	15	0			
Rent	175	0	0			
Rates	20	6	6			
Wages and Insurance	860	10	0			
Feeding Stuffs	1965	9	6			
Fertilisers	245	6	6			
Seeds	28	17	6			
Implement Repairs	116	16	4			
Other repairs and small tools ...	94	6	6			
Fuel and Oil	276	4	4			
Vehicle Taxation and Insurance ...	58	6	6			
Haulage	8	10	6			
Contract Services	48	16	0			
Vet. and Medicines	62	15	0			
Service Fees	10	10	0			
Telephone	12	14	0			
Sundries	146	16	5			
				4209	0	7
NET PROFIT				1029	6	4
				£9662	6	11

FOR YEAR ENDING 31ST MARCH, 1956

	£	s.	d.	£	s.	d.
Sales						
Livestock—Cattle—2 Barren Cows...	96	0	0			
1 Casualty Cow ...	10	0	0			
10 Calves... ...	86	5	0			
Pigs—67 Baconers	1312	16	0			
Poultry	12	10	0			
				1517	11	0
Livestock Produce						
Milk	3060	4	10			
Eggs	141	16	8			
				3202	1	6
Other Receipts						
Ploughing Grant	18	15	0			
Calf Subsidy	45	0	0			
Fertiliser Subsidy	38	7	0			
Private Use of Farm-house	26	0	0			
Private Share of Car Expenses ...	25	0	0			
Produce consumed in House ...	69	0	0			
Sundries	24	12	5			
				246	14	5
Stock on Hand 31st March, 1956						
Livestock—Cattle	1875	0	0			
Pigs	930	0	0			
Poultry	55	0	0			
Crops and Stores	219	0	0			
Cultivations	322	0	0			
Machinery	1295	0	0			
				4696	0	0
				£9662	6	11

BALANCE SHEET AS AT 31ST MARCH, 1956

LIABILITIES

	£	s.	d.	£	s.	d.
Sundry Creditors				81	0	0
Capital at beginning	5035	0	6			
Add—						
Net Profit	1029	6	4			
Dividends	30	0	0			
	6094	6	10			
Less—						
Produce consumed in house ...	69	0	0			
Share of car expenses	25	0	0			
Private use of house	26	0	0			
	5974	6	10			
Less Personal drawings	650	0	0			
				5324	6	10
				£5405	6	10

ASSETS

	£	s.	d.	£	s.	d.
Valuation 31.3.56				4696	0	0
Sundry Debtors				306	0	0
Cash—in Hand	36	7	6			
in Bank	366	19	4			
				403	6	10
				£5405	6	10

year in accordance with taxation policy and advice on the matter can be obtained from the Inspector of Taxes.* From the farmer's point of view, to determine the profit of his farm, rates of depreciation which roughly approximate the actual wearing out of his machinery are required, and in the Table below rates in common use for this purpose are shown:—

TABLE 105: MACHINERY WEAR AND TEAR ALLOWANCES

Class of Machine	Annual Rate of Wear and Tear Allowance
1. Boilers and Engines	5 per cent. or 1s. per £
2. Electrical Installation	$7\frac{1}{2}$ per cent. or 1s. 6d. per £
3. Binders, Mowers and Combine Harvesters	15 per cent. or 3s. per £
4. Motor Lorries	20 per cent. or 4s. per £
5. Tractors	$22\frac{1}{2}$ per cent. or 4s. 6d. per £
6. Sprayers, Flax Pulling Machines	25 per cent. or 5s. per £
7. All other types of Farm Machinery including portable poultry and other Houses	10 per cent. or 2s. per £

General Notes—*Owner-Occupiers*—In this case the farmer is his own landlord and does not pay rent as would an ordinary occupier. Either of two methods may be followed: A separate Bank Account called "Property Account" may be kept into which is paid a half-yearly rent for the farm: in other words a cheque is drawn on the farm account for the rent and paid into the "Property Account." That account then bears all the landlord's charges arising out of ownership, such as Owner's Rates, Income Tax—Schedule "A" and any burdens on the land which are paid under deduction of Tax, such as Feuduty, Ground Rent, Stipend,

* Information is also available in Farmers' Income Tax, published by Her Majesty's Stationery Office, price 1s. 0d.

Multures, Interest on Mortgage, Redemption Annuity payable under the Tithe Act, 1936, Land Tax (if any), and also the cost of repairs to the buildings, these being restricted to those repairs which are necessary to "maintain the rent." By following this system the interest as owner is kept apart from that of the occupier. Under the second method all Property Expenses may be charged to the farm, making no charge for rent. At the end of the year the Profit and Loss Account is charged with what is known as "Nett Schedule A," i.e., the nett rent on which Property Tax is calculated. The second method is recommended.

Wages—If workers are boarded, wages may be dealt with in either of two ways:—

(*a*) By recording the actual cash paid to the employee. This method may involve an adjustment at the end of the year for board, or by

(*b*) Recording the money wages as well as any cost of boarding the employee. The total entry in this case would be the wages they would receive if they were not boarded in. Method (*a*) is the one recommended.

If members of the family are employed there should be included in wages only the actual bona fide payments made to these members. These persons should be treated exactly in the same way as any other employee and a reasonable wage recorded in the Cash Book for their services. The question of board of all employees, including family, will be dealt with at the end of the year.

Private Transactions.—As already mentioned in these notes, all income and expenditure should be recorded in the Cash Book so that the cash may balance. This book contains, therefore, on the receipts side, a record of the receipt of dividends, sales of private property, legacies, sales of investments or any other private transactions, and on the payments side all private and household payments, including tradesmen's bills. This method should be followed unless the farm system is highly developed and there is a separate Bank Account for personal transactions. It is assumed that this is not so. At the end of the year the Accounts owing by and to the farm (shown as part of the Inventory) will exclude all such private transactions. It will be observed that the private transactions are also excluded from the Profit and

Loss Account as they are not sums expended for the purpose of earning the profit but would occur whether or not the land was being farmed.

ANALYSIS OF ACCOUNTS FOR MANAGEMENT PURPOSES

All too often farm accounts are kept solely for determining the profit or loss made during the year, only providing a basis for Income Tax Assessments. Important as this purpose may be, even the simplest accounts have a far greater value when properly used and interpreted, forming a guide to the future planning and management of the farm business. It is assumed the aim of management is to secure the greatest *continuous* profit. The word *continuous* is of particular significance since any form of farming which produces high profits for short periods at the expense of the fixed assets of farming, notably the land, is not good management.

The value of the accounts for management purposes is derived mainly from a comparison with results of similar farms or with "standards" of efficiency based on good farming practice. To make such comparisons possible and also to make calculations easier it is desirable further to simplify the accounts as finally presented in the Trading and Profit and Loss Statement, pp. 696 and 697. As the statement stands, the gross output of cattle, for instance, is made up of five figures, namely, the opening valuation, purchases, sales, calf subsidy received and the closing valuation. It is much simpler and more convenient for subsequent calculations if these are resolved into one figure of the gross output of cattle, thus:—

Closing Valuation	£1875 0 0	
Sales	192 5 0	
Calf Subsidy	45 0 0	
		£2112 5 0
Less		
Opening Valuation ...	1845 0 0	
Purchases...	—	
		1845 0 0
Gross Output of Cattle		£267 5 0

In this instance the final figure represents a surplus, but in other instances, e.g., where a dairy is largely maintained by purchases, the figure could be a deficit and in such a case it would be entered on the cost side of the account.

This process is repeated for each item which appears in valuations, purchases and sales, including crops, feeding stuffs and machinery and, depending on whether the figure is positive or negative, it is entered either on the credit or debit side of the account respectively. In the case of machinery in particular, not only is depreciation included but also all machinery expenses, to obtain a true indication of total machine and power costs incurred. For example:—

	£ s. d.	£ s. d.
Opening Valuation of Machinery...	1450 0 0	
Purchases	nil	
		1450 0 0
Less		
Sales	nil	
Closing Valuation	1295 0 0	
		1295 0 0
Depreciation		155 0 0
Add Other machinery expenses—		
Implement Repairs	116 16 4	
Fuel and Oil	276 4 4	
Taxation and Insurance ...	58 6 6	
Haulage	8 10 6	
Contract Services	48 16 0	
		508 13 8
		663 13 8
Less Private share of Car ...		25 0 0
		£638 13 8

Again, certain items amongst the Other Sales and Receipts can be eliminated by deducting them from the appropriate item on the expenditure side of the account. For example, the actual rent chargeable to the farm business may be regarded as the rent paid less the value of the private use of the farm-house and also in many instances the rents received for

cottages. The appropriate figure in this instance would be:—

		£	£
Rent Paid			175
Less			
Cottage Rents		nil	
Private use of Farm-house		26	
		—	26
Rent chargeable to Farm Business			149

Finally, in the accounts as prepared in the first instance, the profit figure calculated represents the return to the farmer for his manual and managerial labour and interest on capital. The expenditure side of the account does not include any charge for his own or his wife's labour. If at any stage the efficiency of the farmer in using all his resources is to be tested, then an allowance must be made for the work he and his wife do, charged at standard rates of wages.

After the approximate adjustments have been made the trading account now appears (to the nearest £):—

Costs	£	Gross Output	£
Rent and Rates ...	169	Cattle	267
Wages*	1211	Pigs	1758
Feeding Stuffs ...	2012	Poultry and Eggs ...	152
Fertilisers	226	Milk	3088
Seeds	28	Crops	7
Machinery, Power and Transport	639	Miscellaneous ...	44
Miscellaneous Costs ...	328		
	4613		
Surplus of output over costs	703		
	£5316		£5316

* This includes an allowance of £350 for the farmer's manual labour.

Receipts:—Year ending 31/3/56

CASH ANALYSIS

Sheet I

	Cattle	Calves	Baconers	Poultry	Milk	Eggs	Ploughing Grant	Calf Subsidy	Fertiliser Subsidy	Sundries		Private		
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
	48 0 0	14 0 0	95 0 0	4 16 0	210 0 0	3 10 0	15 0 0	7 10 0	8 5 0	18 0 0		15 0 0		
	48 0 0	7 10 0	etc.	etc.	204 6 4	4 2 6	etc.	7 10 0	8 5 0	4 10 0		15 0 0		
	10 0 0	8 0 0	etc.	etc.	196 4 3	4 5 3	etc.	etc.	etc.	etc.		15 0 0		
		etc.			etc.	etc.		etc.		etc.				
					etc.									
Total Receipts	106 0 0	86 5 0	1299 16 0	12 10 0	3072 4 10	141 16 8	18 15 0	45 0 0	38 7 0	24 12 5		30 0 0		
Add amounts owing to farm at end	—	—	108 0 0	—	198 0 0	—	—	—	—	—		Transfer to Balance Sheet		
			1407 16 0		3270 4 10									
Deduct amounts owing to farm at beginning ...	—	—	95 0 0	—	210 0 0	—	—	—	—	—				
	106 0 0	86 5 0	1312 16 0		3060 4 10	141 16 8	18 15 0	45 0 0	38 7 0	24 12 5				

Payments:—Year ending 31/3/56

CASH ANALYSIS

Sheet I

	Pigs	Poultry	Rent	Rates	Wages etc.	Feeds	Fertilisers	Seeds	Implement Repairs	Other Repairs and Small Tools	Fuel and Oil	Vehicle Taxation	Haulage	Contract
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
	55 0 0	22 15 0	87 10 0	10 3 3	17 10 0	70 0 0	35 0 0	9 8 6	6 7 0	0 7 6	20 14 0	25 0 0	0 16 0	22 0 0
			87 10 0	10 3 3	17 10 0	26 0 6	16 10 0	6 4 6	12 15 0	1 14 0	20 14 0	12 10 0	2 5 0	etc.
					16 7 6	35 16 0	etc.	etc.	etc.	26 10 0	26 7 6	etc.	1 10 0	
					etc.	40 10 0	etc	etc.		etc	etc.		etc.	
					etc.	etc.	etc.							
						etc.								
						etc.								
Total Payments	55 0 0	22 15 0	175 0 0	20 6 6	860 10 0	1985 9 6	251 6 6	28 17 6	116 16 4	94 6 6	276 4 4	58 6 6	8 10 6	48 16 0
Add amounts owing by farm at end of year ...	—	—	—	—	—	45 0 0	36 0 0	—	—	—	—	—	—	—
						2030 9 6	287 6 6							
Deduct amounts owing by farm at beginning of year	—	—	—	—	—	65 0 0	42 0 0	—	—	—	—	—	—	—
Balance to Profit and Loss Statement	55 0 0	22 15 0	175 0 0	20 6 6	860 10 0	1965 9 6	245 6 6	28 17 6	116 16 4	94 6 6	276 4 4	58 6 6	8 10 6	48 16 0

CASH ANALYSIS

Payments:—Year ending 31/3/56 *(continued)* **Sheet 2**

	Vet. and Med.	Service Fees	Telephone	Sundries				Private						
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
	15 15 0 10 12 6 etc.	3 3 0 4 10 0 etc.	6 5 0 6 9 0	2 10 0 4 6 0 5 6 6 etc.				20 0 0 etc. etc.						
Total Payments	62 15 0	10 10 0	12 14 0	146 16 5				650 0 0						
Add amounts owing by farm at end of year ...	—	—	—	—				Transfer to Balance Sheet						
Deduct amounts owing by farm at beginning of year	—	—	—	—										
Balance to Profit and Loss	62 15 0	10 10 0	12 14 0	146 16 5										

Of the produce consumed in the farm-house, £21 is allotted to Pigs, £20 to Poultry and £28 to Milk.

The accounts as now prepared and the measures of efficiency which can be calculated from them are of use only when compared with accounts for other farms or with " standards " based on the accounts of other farms of similar type and size. It is difficult to provide comparative accounts for use in all parts of the country. Those used in subsequent pages are based on the results of certain kinds of West Country farm where the example is situated. Farmers wishing to carry out an analysis of their own records are advised in the first instance to discuss the matter with the District Advisory Officer or Provincial Agricultural Economist.

The logical sequence in farm analysis and planning is to consider:—

(*a*) matters which concern the farm in general;

(*b*) the efficiency of individual farm enterprises or efficiency in the use of separate farm resources, e.g., labour, capital, machinery;

(*c*) various alternative methods and plans of farming.

THE EFFICIENCY OF THE FARM AS A WHOLE

The first and simplest test is to compare the items of cost and output, making up the simplified account with the " standards " which are, most commonly, the average results for groups of similar farms. It is desirable to make the comparison with a group of farms of similar size as well as type, but absolute identity of size is seldom attainable and, to eliminate the effect of size variation, the comparison should be made in terms of costs and outputs per acre.

The table on the following page discloses a number of interesting facts, the foremost being that the surplus of output over expenses, £9·9 per acre (i.e., profit after charging farmer's and wife's labour) is *lower* than average.

Moreover, wages and machinery expenses are higher than average whilst total costs are lower. The figures for output show the highest returns per acre from milk and emphasise the greater specialisation on dairying of this farm compared with others in like circumstances. Total output per acre is £5·5 less than the group average.

COMPARISON OF COSTS AND OUTPUT PER ACRE: EXAMPLE FARM AND GROUP AVERAGES

Item	Example Farm		Group Average
		£ per acre	
Costs			
Rent and Rates	2·4		2·2
Wages (including farmer and wife)	17·1		14·7
Feeding Stuffs	28·3		37·1
Fertilisers	3·2		2·3
Seeds	0·4		1·2
Power and Transport ...	9·0		7·1
Miscellaneous	4·6		4·2
Total costs	65·0		68·8
Output			
Cattle	3·8		6·6
Pigs	24·8		38·6
Poultry and Eggs ...	2·1		3·7
Sheep and Wool ...	—		1·7
Milk	43·5		26·4
Crops	0·1		3·0
Miscellaneous	0·6		0·4
Total Output ...	74·9		80·4
Surplus of output over expenses ...	9·9		11·6

The first comparative examination of the account is useful chiefly in suggesting various leads for further more intensive examination but still related to the farm as a whole. Firstly, the lower than average gross output per acre needs investigation because, although it is not infallibly the case that high gross output is accompanied by high profits, in general, studies of farm profitability indicate this trend. In other words, the higher the gross output or the more intensive the system of farming the higher is likely to be the profit.

The output of a farm is the result of two factors. Firstly,

it is affected by the combination of enterprises which make up the system of farming. Certain enterprises contribute a greater volume of output per acre devoted to them than others. Market gardening, for example, results in higher output per acre than ordinary arable farming, whilst dairy farming generally produces a greater value of output per acre than store rearing or even fattening cattle on grass. Secondly, output regardless of the system of farming employed, is affected by levels of yields achieved whether these are for crops or livestock and livestock produce. Thus, in explaining any given level of output, it is useful to separate the effect of the system of farming on output from the effect of levels of yield on output and to consider each individually. The means to do this are available in the form of a system index and a yield index.

SYSTEM INDEX

The system index provides a means of comparing the efficiency of the combination of enterprises on an individual farm with the average for a group of farms. To calculate the system index first calculate the standard output of the farm. By standard output is meant the output when yields per acre or per animal are about average. Then compare the standard output of the farm with the standard output of the group and express it as a percentage of the latter. If the answer (the index) is above 100 the combination of enterprises, although perhaps not the best possible, is better than average. If the answer is below 100 then the combination of enterprises is below standard.

Obviously the first requirement for this calculation are suitable standards. These are given in Table 106.

The standard output closely approximates to the value of the output produced from each unit in a year under reasonably good conditions of management. In the case of directly productive stock such as dairy cows, ewes or sows the standard is based on the amount of produce sold, but in the case of other kinds of stock, e.g., young cattle, the annual value of the output corresponds to the growth in value one could expect to take place in a year. Standard output for sale crops are shown but not for crops customarily grown for feeding on the farm. In the case of feed crops the value is

TABLE 106: STANDARD OUTPUTS FOR LIVESTOCK AND CROPS*

Livestock	Standard Output £ per head
Dairy Cows	105
Beef Cows	30
Other Cattle—2 years and over ...	20
1–2 years	15
Under 1 year ...	15
Ewes	10
Rams	—
Store Lambs	3
Sows	60
Baconers Fattened	15
Boars	—
Poultry over 6 months	3
„ under 6 months	1

Crops	£ per acre
Wheat for sale	30
Barley, dredge corn and beans for sale ...	25
Oats, for sale	23
Peas, threshed	30
Peas, green	85
Potatoes	95
Sugar Beet	80

* "The Farm as a Business": Ministry of Agriculture, Fisheries and Food.

taken into account in the values placed upon the livestock to which they are fed.

Applying these standard outputs to the example farm, the situation is:—

	Average No.*	Standard Output per unit £	Total £
Dairy Cows	21·5	×105	2257·5
Young Cattle over 2 years	4·5	×20	90·0
1–2 years ...	5·5	×15	82·5
under 1 year	11·5	×15	172·5
Sows	7·5	×60	450·0
Baconers fattened ...	67	×15	1005·0
Hens	50	×3	150·0
Pullets	100	×1	100·0
Crops			
Nil			
Standard Output of Farm—Total			£4307·5
Per acre			£60·7

A similar calculation for the comparable group of farms gave a standard output per acre of £75 2s.

Expressing the farm as a percentage of the group result.

$$\frac{60 \cdot 7}{75 \cdot 2} \times 100 = 80 \cdot 7\% = \text{System Index}$$

The System Index in this instance indicates that the combination of crops and livestock, i.e., the system of farming followed by the example farm, is only 80·7 per cent. as efficient as other comparable farms assuming approximately average yields and conditions.

There is therefore good reason to examine critically the planning of the farm and consider introducing new enterprises or devoting more time and resources to the more intensive enterprises.

* Average of opening and closing valuations.

YIELD INDEX

It does not follow from a low system index that a farm is grossly unprofitable nor conversely in the case of a farm with a high system index all is well. In terms of profit the results of a poor farm system can be mitigated by higher than average yields or the effects of a good system can be completely nullified by low livestock and crop yields whether due to management or adverse natural conditions. It is always instructive to follow the calculation of the system index with a calculation of the yield index. The yield index of a farm is simply the actual output of the farm expressed as a percentage of the standard output:—(Actual Output $\div$ Standard Output) $\times$ 100

For the example farm it is:—$\frac{74{\cdot}9}{60{\cdot}7} \times 100 = 123$

In this case much of the ill effect of the poor system is compensated by better than standard yields. Nevertheless, better results could be obtained by improving the system whilst maintaining yields.

Unless both system and yield index are high there are no grounds for complacency.

EFFICIENCY IN THE USE OF FARM RESOURCES

Turning now to a more detailed examination of the farm business, it is necessary to examine how effectively the inputs are used. For some of the inputs little more can be done, or even needs to be done, than refer once again to the comparison of costs per acre as outlined on page 706. Costs which appear comparatively high need careful examination to determine whether reduction without detriment to the farm as a whole is possible. In some instances it is equally rewarding to examine items of expenditure which appear unduly low, e.g., that on fertilisers, where more generous use may bring about a more than proportionate increase in returns.

An omnibus measure of the overall efficiency of the farm in the use of its resources is given by the figure of gross output per £100 costs which is calculated quite simply: (Gross output $\div$ total expenses) $\times$ 100.

Too great a reliance must not be placed on such a figure alone. A high output per £100 costs need not always denote efficient and profitable farming because frequently this result is obtained on farms where costs, output and profits are low. In other words it might result from a system of farming where profits per unit of produce, i.e., per gallon of milk or ton of cereals, is high but the total output is small. On the other hand, successful systems of farming occur where lower output per £100 costs is associated with high total profits because the volume of output is great. The measure taken in conjunction, however, with the measure of gross output per acre can be useful.

Certain items of farm inputs, because of their importance as elements of cost or their scarcity, deserve individual attention. Among these are labour and capital. Feeding stuffs, too, for livestock types of farming are particularly important, but efficiency in the use of feed is best dealt with in conjunction with the efficiency of the livestock enterprises.

Labour—The two measures which can most readily be calculated to indicate the degree of efficiency in the use of labour are Gross Output per £100 Labour employed and the Labour Index. The gross output per £100 labour employed is the simplest measure and is obtained by:—

$$\left(\text{Total Output} \div \underset{\substack{\text{including the value of the} \\ \text{labour of the farmer and} \\ \text{his family}}}{\text{Total Wages}} \right) \times 100$$

This measure is subject to the same failing as gross output per £100 total costs. Output per £100 labour can be low not because labour is inefficient so much as because output is low due to poor yields or a poor system of farming. Such a measure, therefore, should only be used in conjunction with others such as gross output per acre or the system index which will also help to explain and isolate the causes of high or low output.

Labour Index—Involves more work in its calculation and, like the system index, is based on comparing conditions on the farm with " standards " based on average or reasonably good conditions of management. The measure is calculated by estimating what the " standard " labour requirements of the farm are in terms of man-days of work and comparing this with the actual total labour employed.

TABLE 107: STANDARD LABOUR REQUIREMENTS*

Livestock	Labour Requirements (man-days per head)
Dairy Cows—tie up cowshed	19
yard and parlour	12
Beef Cows	3
Other Cattle—2 years and over	2
1–2 years	3
under 1 year	$4\frac{1}{2}$
Ewes	$1\frac{1}{2}$
Rams	1
Store Lambs	1
Sows	5
Baconers Fattened	$1\frac{1}{2}$
Boars	2
Poultry—over 6 months	$\frac{1}{4}$
under 6 months	$\frac{1}{4}$

Crops	Man-days per acre
Wheat—binder	4
combine harvester	2
Barley, dredge corn, beans—binder	4
combine harvester	2
Peas, threshed—binder	4
combine	3
Peas, green	15
Potatoes	20
Sugar Beet	20
Fodder Roots	20
Kale—folded	7
" cut	14
Hay and Silage	$2\frac{1}{2}$
Grazing	$\frac{1}{2}$
Fallow	$\frac{1}{2}$

* "The Farm as a Business": Ministry of Agriculture, Fisheries and Food.

The first requirements for the calculation are suitable standard labour requirements which are set out opposite.

The standard labour requirements which are given do not make an allowance for labour expended in general maintenance work around the farm—hedging, ditching, road-mending, and so on. On most farms such work absorbs from 15 to 20 per cent, of the total, depending upon the condition and layout of the farm and the calculated standard labour requirements for any farm should, therefore, be increased by something approaching these amounts.

The calculation of the Labour Index for the example farm is:—

CALCULATION OF LABOUR INDEX FOR EXAMPLE FARM

Livestock	Average No.	Man-days required per head	Total
Dairy Cows	21·5	×19	408·5
Bull	1	× 5	5·0
Young stock—over 2 years...	4·5	× 2	9·0
1–2 years ...	5·5	× 3	16·5
under 1 year	11·5	× 4½	51·75
Sows	7·5	× 5	37·5
Baconers Fattened	67	× 1½	100·5
Hens...	50	× ¼	12·5
Rearing Pullets	100	× ¼	25·0
Total Livestock Labour requirements ...			666·25

Crops	Acreage	Man-days per acre	Total
Mixed Corn	5·5	× 4	22·0
Mangolds	3·0	×20	60·0
Kale	6·5	× 7	45·5
Hay	21·0	× 2½	52·5
Grazing	34·0	× ½	17·0
Total Crop Labour requirements			197·0

Total man-days required by stock and crops...	863·0
Add 15% for maintenance... ...	129·0
	992·0

Labour available on farm

Farmer and wife, say	350 man-days
1 cowman	350 ,,
1 tractor driver	320 ,,
Casual labour	90 ,,
Total	1110

$$\text{Labour Index} = \frac{\text{total labour required}}{\text{total labour available}} \times 100$$

$$= \frac{992}{1110} \times 100$$

$$= 90$$

A labour index of 90 indicates efficiency significantly below standard and justifies extensive examination of the organisation of the work on the farm. A low index does not, of course, always mean a low order of labour management. It might be due to difficult working conditions, bad farm layout, and so on, but whatever the cause it serves to draw attention to the problem of full utilisation of labour.

Capital—There are two measures which indicate how well the capital in the business is used. The first is Gross Output per £100 Capital. This measure is calculated as follows:—

$$\frac{\text{total gross output}}{\text{total capital}} \times 100$$

For this purpose the capital of the farm is taken as the average of the opening and closing valuations plus an addition for cash required to be kept in hand and at the bank for the purpose of the day-to-day needs of the farm. The latter element of capital is sometimes difficult to estimate and it will suffice to base the calculation on the opening and closing valuations. For the example farm the calculation is:—

$$\frac{\text{gross output}}{\text{average of opening and closing valuations}} \times 100$$

$$= \frac{5316}{4560} \times 100$$

$$= £116{\cdot}5$$

This compares with a Gross Output per £100 Capital of £142 for the comparable group and indicates a lower productivity of capital than average.

Productivity of capital may also be indicated by what is termed the rate of capital turnover or, in other words, the time taken to realise output to the value of the capital invested, assuming that the rate of production is more or less constant throughout the year. A high rate of capital turnover is not necessarily associated with high profits, but it might be of importance in cases of shortage of capital. Certain enterprises like pigs, poultry or milk production yield a higher rate of turnover than, say, beef cattle or cash crop production. For the example farm the rate of capital turnover is:—

$$\frac{\text{average capital invested}}{\text{total gross output}} \times 12 = 10{\cdot}3 \text{ months}$$

whereas the rate of turnover for the comparable group of farms is 1 in $8\frac{1}{2}$ months, yielding, therefore, a result consistent with the lower output per £100 capital on the example farm. Again there is a case for attempting to intensify the use of the existing capital to increase its productivity.

EFFICIENCY OF INDIVIDUAL FARM ENTERPRISES

Simple figures of yields of crops per acre or livestock products per head of stock constitute useful measures of performance which are in constant use by farmers everywhere. In addition there are, however, various other measures which may be even more useful although they might entail more time in calculation.

Crops—In addition to simple figures of average yields per acre three measures of efficiency are worth mentioning.

The first two relate to the cash crop side of farming, the third to feed crops.

For cash crops it is useful to calculate a cash crop system index in much the same way as the system index was calculated for the farm as a whole. The manner of calculation is to multiply the acreages of cash crops grown on the farm by the standard outputs per acre shown in Table 106 and to express this figure as a percentage of the figure calculated in the same way for the comparable group of farms. The cash crop system index would therefore be:—

$$\frac{\text{cash crop standard output of farm}}{\text{cash crop standard output of comparable group}} \times 100$$

A low index figure denotes a tendency to emphasise low value crops as compared with other farms and vice versa. Profits tend to be greater the higher the system index.

Again it is possible and useful to calculate a cash crop yield index to use in association with the system index, the calculation being:—

$$\frac{\text{actual cash crop output of farm}}{\text{cash crop standard output of farm}} \times 100$$

A low figure denotes either low physical yields of crops, or, since the calculation is in terms of value of the crop, it could also be caused by poor marketing, poor quality and the achievement of low prices.

Feed Crops—The productivity, or efficiency, of the area of a farm devoted to feed crops is denoted by the feed acres required to support an animal unit. This constitutes a measure of the intensity of stocking—the lower the feed acres per animal unit the more intensive the stocking and in general the higher the profit.

The calculation of feed acres per animal unit requires estimation of feed acres on the one hand and the conversion of the numbers of livestock of different kinds on the farm to a common denominator of animal units.

In estimating feed acres two complications arise. On many farms, unlike the example farm, a proportion of some

crops, especially cereals, may be sold and the remainder fed. In such cases as close an estimate as possible must be made in terms of acres of the proportion sold and the proportion fed. Secondly, for comparative purposes the situation is complicated by the common but varying use made of substantial quantities of purchased feed. To compare the feed acres per animal unit from a farm using little or no purchased feeding stuffs with the feed acres per animal unit from farms or groups of farms using large quantities is misleading. Some adjustment for the quantities of purchased feed used is therefore necessary. Since the buying of purchased feed is virtually equivalent to renting additional land, the simplest method of adjustment is to add to the acreage of fodder crops an acreage roughly equivalent to that required to produce the purchased feed on the farm, assuming one ton of purchased concentrate equals the addition of one acre to the feed acreage. Where the quantities of purchased foods have not been recorded an estimate of the tonnage can be made by dividing the total expenditure by the estimated average price.

TABLE 108: CONVERSION OF LIVESTOCK TO ANIMAL UNITS

Type of Livestock		Animal Units
1 Dairy Cow	=	1
1 Beef Cow	=	1
Other Cattle—over 2 years ...	=	1
1–2 years	=	$\frac{2}{3}$
under 1 year ...	=	$\frac{1}{3}$
1 Bull	=	1
1 Ewe	=	$\frac{1}{5}$
1 Ram	=	$\frac{1}{10}$
1 Store Lamb	=	$\frac{1}{15}$
1 Sow	=	$\frac{1}{2}$
1 Baconer Fattened	=	$\frac{1}{7}$
1 Boar	=	$\frac{1}{4}$
1 Poultry—over 6 months	=	$\frac{1}{50}$
under 6 months	=	$\frac{1}{200}$

For the example farm which is wholly devoted to feed crops the calculation of feed acres is:—

Feed crops grown	70 acres
Purchased foods—	
63 tons bought for £2012 ...	63 ,,
Total feed acres	133

The conversion of the livestock on the farm to animal units may be done in accordance with values for each class of stock given in Table 108. These values place stock roughly in relation to one another according to their total feed requirements and make possible comparison between diverse types.

The calculation of the animal units for the example farm, using the conversion of values given in Table 108, is therefore:

Type of Livestock	Average No.		Conversion Value	Animal Units
Dairy Cows	21·5	×	1	21·5
Bulls	1	×	1	1·0
Other Cattle—over 2 years	4·5	×	1	4·5
1–2 years ...	5·5	×	$\frac{2}{3}$	3·7
under 1 year	11·5	×	$\frac{1}{3}$	3·8
Pigs—Sows	7·5	×	$\frac{1}{2}$	3·75
Baconers Fattened ...	67	×	$\frac{1}{7}$	9·5
Poultry—				
Hens	50	×	$\frac{1}{50}$	1·0
Pullets under 6 months ...	100	×	$\frac{1}{200}$	0·5
Total				49·25

$$\text{Feed acres per animal unit} = \frac{133 \text{ feed acres}}{49{\cdot}25 \text{ animal units}}$$

$$= 2{\cdot}7 \text{ feed acres per animal unit}$$

The average for the comparable group of farms was 2·0 feed acres per animal unit, which indicates a significantly lower than average intensity of stocking.

Efficiency of Livestock Production—As previously stated some indication of the efficiency of different classes of livestock is afforded by simple figures of yields per animal, such as the yield of milk per cow, number of lambs born alive and weaned per ewe, the number of pigs born alive and weaned per sow and number of litters per sow per year. All these are useful but they can be supplemented by other more comprehensive measures. Before dealing with such measures it is well to deal with one point concerning milk yields per cow. The lactation yield of the individual cow is of considerable use as a guide to breeding and selection, but it is not necessarily so good a guide to better management of a herd as a whole. The profitability of the herd is affected not only by lactation yields but also by the numbers of cows in milk and the length of the dry period. More important, perhaps, than lactation yield in the influence on the profitability of milk production, is the average annual yield per cow in the herd. This is calculated by dividing the total milk produced in the year by the average number of cows in milk and dry.

Even the average milk yield per cow in the herd is not a sufficiently inclusive measure for all purposes. The unit of production includes not only cows but also young cattle being reared for replacements (except in "flying herds") and profitability is influenced greatly by the proportion of young stock to productive adult cattle. For comparative purposes such variations in proportions must be taken into account and this is done by expressing output in terms of output per animal unit in the herd.

In the case of the example farm, total animal units in the form of dairy cattle number 34·5 and the total output from the cattle unit amounts to £3355, yielding a total output per animal unit in the herd of £97, which compares with £82 for the group.

Similar calculations for the output per animal unit can be carried out for each separate class of livestock.

So much for measures of efficiency or measures of performance as they are sometimes called. Some of these

might at first seem laborious to calculate but in practice they are simple and their value becomes more apparent with use. The measures which have been described do not exhaust the list. Experimentation with farm accounts and records will disclose many more of particular value in the circumstances and conditions of each individual farm.

Having examined the farm business in the light of the measures discussed, the final step is to institute improvements. These are frequently numerous and the relative advantages of the alternatives may not always be obvious. It is essential, therefore, that the choice between alternatives should not be haphazard but based upon a systematic assessment of the contribution each can make towards the profit of the farm. The means to make such systematic assessment exists in the technique known as partial budgeting.

PARTIAL BUDGETING

The use of the word partial in connection with budgeting has some significance because it may be taken to refer to two characteristics of the technique. First, partial budgeting is concerned with alterations to an existing plan of farming rather than wholesale replanning which in any case is frequently impossible if not undesirable and, secondly, it takes into account the fact that costs incurred in farming, as in other businesses, are of two kinds, fixed and variable. The fixed costs of farming are those which do not vary either with the volume or kind of production undertaken and closely approximate to those referred to generally as overheads. They include such items as rent and rates, depreciation of equipment, business subscriptions, office expenditure and very frequently, too, a substantial part of the labour cost, particularly in the case of family farms where the labour force is rigid. Since these costs are fixed the partial budget is not concerned with them but takes into account only those costs which vary directly with the kind and volume of production undertaken. The variable costs include such items as fuel and oil, fertilisers, feeding stuffs, casual rather than regular labour, and so on. In determining, therefore, the relative merits of different courses of action by means of a partial budget only variations on existing levels of costs and incomes are taken into account. It is less likely that

items which should appear in the budget are not missed if a set form is employed, the most convenient being to group the items under the headings "extra costs incurred" and "income foregone" on the one hand and "costs saved" and "income gained" on the other.

The method is best illustrated by an example. In the case of the example farm it was seen that the feed acres per animal unit were rather higher than for the group, indicating a lower than average efficiency in the use of land. One means of putting this right would be to reduce the area of land devoted to livestock and to produce some cash crop, a possibility in this case. The present level of manuring amounted to an equivalent of £3·2 per acre over the whole farm but on grassland alone it was estimated to have been lower than this, say about £2·5 per acre. By doubling the dressing of fertiliser it was estimated that the productivity of grassland could be increased sufficiently to release 10 acres for cash cropping while at the same time maintaining stock numbers. The problem resolves itself, therefore, into estimating what gain would result from reducing the area of grass to 46 acres and growing 10 acres of wheat. The partial budget would appear as follows:—

Extra Costs Incurred	£	*Costs Saved*	£
Extra fertilisers to 46 acres of grassland at £2·5 per acre	115	Fertilisers on 10 acres grass ...	25
Extra fuel costs in applying additional quantities of fertiliser	2	Fuel costs of applying fertilisers on 10 acres	1
Fertilisers on 10 acres of wheat	40	Annual share of the cost of establishing grass, say £2 per acre	20
Seed for 10 acres of wheat ...	40		
Extra fuel for cultivating wheat ground	10		
Contract combining	38		
Contract baling of straw ...	12		
Drying charges	31		
Income Foregone		*Income Gained*	
Nil		25 cwt. wheat per acre at 27s. per cwt.	338
		1 ton straw per acre at £4 10s. per ton	45
Balance in favour of growing 10 acres of wheat	141		
	£429		£429

The budget shows a substantial balance in favour of growing some wheat.

The value of making a budget for all important changes in a farm plan is that the financial advantages and disadvantages are systematically set out. For this reason important considerations are less likely to be overlooked.

It is necessary for the estimates of changes in inputs and outputs consequent upon a change in plan to be as accurate as possible. In particular, one must guard against a common human failing of being too optimistic in assessing the returns expected from new ventures. Budgets must be made on the basis of conservative estimates.

FORESTRY

POLICY, GRANTS AND CONTROLS

FOREST POLICY

HOME grown timber is insufficient to meet national demands. In 1919 the Government set up the Forestry Commission, which now operates under the direction of the Minister of Agriculture and the Secretary of State for Scotland, charged with the promotion of afforestation and the maintenance of adequate reserves of growing timber in Great Britain. This is achieved partly by establishing and maintaining nationally owned forests, partly by the encouragement of private woodland owners and partly by research and education. In Northern Ireland, a similar policy is pursued by the Forestry Division of the Ministry of Agriculture, but the following notes relate more particularly to England, Scotland and Wales.

Statistics—The area of ground (1957) classified as woodland is some 4 million acres, equivalent to 7 per cent. of the total land area. It is estimated to carry 4000 million cubic feet of timber (in true measure, under bark). The annual growth amounts to about 130 million cubic feet, of which 90 million cubic feet are harvested, the balance of 40 million cubic feet being left standing to increase reserves.

In contrast, the annual consumption of timber and wood products, such as paper pulp for newsprint, amounts to about 1,100 million cubic feet. Thus, at present, over 90 per cent. of requirements must be imported, whilst the reserve is only equal to four years' normal consumption. The average consumption of timber or timber products per head of population is 20 cubic feet per annum, which is equivalent to the sustained output of ¼ acre of forest.

The Commission itself already holds 1 million acres of plantations, and has a reserve for future planting of 0·4 million acres. It is acquiring, by gradual stages, a further 1·6 million acres for afforestation. This land must be of least value for food production and is commonly scrub or felled woodland, hill ground, moor, or heath. Agreement with the appropriate Agricultural Department is required before an area is transferred from grazing use. Private

owners manage 0·5 million acres under plans approved by the Commission, and hold a further 1·5 million acres managed otherwise. Besides this area of 5 million acres, eventually forming our reserve of standing timber, about 300,000 acres of woods are maintained primarily as shelter for crops or stock, cover for game, or simply for the amenity value.

The Forestry Commission controls the felling of all existing woods, and normally insists on their replacement. Should the owner be unable to carry out replanting, the Commission is ready to consider purchasing or leasing the land. Otherwise, responsibility to restock the ground and maintain the plantations rests with the owner, who may obtain assistance in several ways.

AGENCIES FOR ASSISTING WOODLAND OWNERS

It is worth while employing a full-time forester to ensure maximum returns in the case of several hundred acres of woodland, but a common difficulty with small acreages is that the need for thinning, felling or replanting arises only at intervals of several years. Hence, the help of a forestry adviser who is more constantly in touch with local conditions, and particularly with markets and ruling prices, is well worth while.

Free Technical Advice from Forestry Commission—Initial advice on all aspects of afforestation and timber production is given free of charge by the Forestry Commission, but the Commission does not normally undertake detailed management of woodlands or the actual work of afforestation. Applications for advice should be made to the local Conservator of Forests, whose address will be found in the booklet *Grants for Woodland Owners*, obtainable free from the Secretary, Forestry Commission, 25, Savile Row, London, W.1. A list of the Commission's technical publications (Sectional list No. 31) is obtainable from that address or from H.M. Stationery Office.

Co-operative Forestry Societies—These are independent associations operating throughout Scotland and in many districts of England and Wales. In return for a small subscription, members have the services of a professional forester for advice on planting or the marketing of produce, and most societies undertake the actual operations for an

agreed fee or commission. Societies also arrange bulk buying of young trees, tools, and materials at favourable rates.

Planting Contractors—The planting of woods, and their subsequent maintenance for a stated period of years, is undertaken by firms of planting contractors for an agreed charge. Some timber merchants maintain a planting service which can be employed to restock land cleared by felling.

Forestry Consultants—These are professionally qualified men who advise on woodland management, or actually undertake it, for an agreed fee. Many land agency firms offer a similar service.

Forestry Societies—The Royal Scottish Forestry Society, and the Royal Forestry Society of England and Wales, organise meetings and excursions at which woodland problems are discussed; they also issue quarterly journals.

GRANTS AND LOANS

The financial assistance detailed below is available to most owners of woodlands, but those with large acreages may be required to participate in a Dedication or Approved Woodlands scheme before planting grants are given. The smallest area qualifying for grant is normally two acres on one estate in one year. Further details and application forms can be obtained from the local office of the Forestry Commission. Prior approval of the Commission is needed before work begins and the finished work is inspected before payment is made. Rates of grant are subject to periodical revision.

Small Woods Planting Grant—£17 per acre, of which £12 15s. 0d. is payable in year of planting and £4 5s. 0d. five years later, provided woods have been properly maintained. This meets about one third the cost of planting which varies widely, but averages £50 per acre.

Thinning Grant—£3 15s. 0d. per acre on first and second thinnings of young plantations within certain size limits, to ensure that this essential treatment repays the owner.

Poplar Planting Grants—Either £8 10s. 0d. per acre for minimum of two acres, spaced between 18 and 24 ft.

apart, *or* 2s. per tree for a minimum of 100 trees, spaced not less than 18 ft. apart. Approved varieties must be used.

Scrub Clearance Grants—Payable, in addition to Planting Grants, for land to be planted under Small Woods, Dedication or Approved Woodlands Schemes. £13 10s. 0d. per acre if land costs over £27 per acre to clear; £8 10s. 0d. per acre if land costs between £17 and £27 to clear.

Loans—Granted by Forestry Commission in approved cases, and subject to security, to provide capital for re-stocking woodlands. Usually for thirty years; interest must be paid from outset, but repayment of capital may be deferred for 15 years. Interest rates vary but are currently around 7 per cent.

Shelterbelts—Shelterbelt planting may qualify for a grant of up to 50 per cent. of the net outlay in hill country or 33⅓ per cent. elsewhere provided it forms part of a farm improvement scheme. In such cases, application should be made to the agricultural authority; this grant is an alternative to that of the Forestry Commission.

DEDICATION, APPROVED WOODLANDS AND PLANS OF OPERATIONS

Owners of substantial acreages of woodland are encouraged to take part in schemes for the Dedication of their woods, or alternatively, the Approval of their management, under the terms of a Plan of Operations. In general, planting grants are only payable to these owners if they enter into such schemes, though exceptions are made for small or scattered woods.

The Plan of Operations is a simple document prepared on standard forms supplied free of charge by the Forestry Commission. It includes a description and a map of the woods, and a simple inventory of their tree crops. This is followed by a statement of the owner's intentions for managing them and a schedule showing the areas he proposes to plant, thin, or fell in the coming five years. Forms for recording this work on completion are available and provision made for revising the Plan every five years. Once the Plan has been approved by the Commission, management rests with the owner who is allowed considerable flexibility, if he wishes, to

vary his proposals. A Commission forest officer visits the woods at least once a year, to discuss progress and agree grants due for payment. The rates of grant are subject to periodical revision.

Dedication—This is the most favoured arrangement for assistance, but involves a legal undertaking by the owner:—

(*a*) not to use the lands for purposes other than forestry, and
(*b*) to work them in accordance with the approved Plan of Operations.

If and when the land changes hands, the first obligation (*a*) is still binding, and the successor in title is invited to continue the approved management in return for the appropriate grants.

Grants payable under Dedication are:—

(1) Planting Grant of £17 per acre for all land planted, replanted, or otherwise re-stocked.

(2) Maintenance Grant of 5s. 6d. per acre per annum on all woods covered by (1), for 15 years after re-stocking.

(3) Maintenance Grant of 5s. 6d. per acre per annum on all productive woods *not* covered by (1) running for 15 years from date of Dedication.

Approved Woodlands—For such woods, a Plan of Operations must be approved and followed, but no legal undertaking binds the land. Only a planting Grant is payable, at the rate of £8 10s. 0d. per acre; of this, £6 7s. 6d. is payable in the year of planting, and £2 2s. 6d. five years later.

LICENSING OF FELLING

In order to safeguard the national reserve of standing timber, it has proved necessary to control felling and to require re-planting, where appropriate, of cleared land. These controls are exercised by the Forestry Commission under the Forestry Act, 1951, and applications for felling licences should be made to the Commission's local office. The Act provides for certain exceptions, the chief being trees standing in gardens, orchards, churchyards, or public open spaces; dangerous trees; trees not more than 3 in. thick, measured 5 ft. from the ground; trees not more than 4 in.

thick, similarly measured, *if removed in thinning a crop*; *coppice* or *underwood*, not more than 6 in. thick, similarly measured. It should be noted that hedgerow trees are *not* exempt.

Apart from these general exceptions, a landowner may fell for his own needs up to 825 hoppus cubic feet on any one estate in any one quarter; of this amount, up to 150 cubic feet may be disposed of, without a licence.

Replanting Conditions—Where, as is normally the case, replanting conditions are attached to the licence, the owner is required to re-stock the cleared ground in an approved manner within five years of the date of felling. Applications for planting grants and also, if required, for loans to assist in carrying out the work, may be made. The young plantations must be properly maintained for at least ten years.

TREE PRESERVATION ORDERS

These are legal directions made by local planning authorities under the Town and Country Planning Acts, 1947, to ensure the preservation of trees for amenity and landscape values. They may apply to individual trees or to whole woods, and may even extend to the control of lopping branches. Trees growing on land covered by the Dedication, or Approved Woodlands schemes, or by other grants or advances from the Forestry Commission, are exempt; so also are dangerous trees and areas of felled woodlands.

When proposing to make a Tree Preservation Order, the planning authority must notify the owner and other parties concerned; any objections to the Order must be made within 28 days.

Claims for compensation for any financial loss suffered are permissible. Once an order is effective, it may control both the felling and the restocking of the land, and continues in force should the land change hands.

Section 13 of the Forestry Act, 1951, provides that in cases where an owner wishes to fell trees which are subject to a Tree Preservation Order, and which also require a Felling Licence, application is made to the Forestry Commission for the Licence, stating that a Tree Preservation Order applies. The Commission then consult the local planning authority concerned, so that any necessary adjustment can be made as between forestry considerations and local amenities.

TAXATION OF WOODLANDS

The practice of the Inland Revenue authorities in assessing the income from woodlands, or their value for estate duty after a death, differs from that followed for other kinds of property, since special concessions have been granted under various Finance Acts. Where, however, trees, shelterbelts or small woods form only a minor part of an agricultural property, it is unlikely that they will be separately assessed.

Income Tax—All woodlands are assessed, in respect of ownership, for Schedule A property tax, but only on the basis of the *unimproved* value of the land; this is assumed to be worth a rent of only a few shillings per acre per year. Expenses of maintenance, etc., are deducted to arrive at the net amount taxable.

In the absence of any other arrangement, woodlands are also assessed, in respect of occupation, under Schedule B, or the "assumed profit," which is taken as one third of the gross Schedule A figure. This tax is seldom more than a small amount, but remains payable whether a profit is actually made or not.

As an alternative to Schedule B taxation, an owner may elect to place commercially managed woods, or any portion of them recently replanted, under Schedule D. In that event, accounts of profit and loss must be kept, but only the actual profit is taxed; further, an owner may, within limits, offset any losses against income from other sources.

In general, it pays best to keep the older, more profitable woods under Schedule B, and to put the younger ones which are not yet profitable, under Schedule D. Any grants received rank as a trading receipt under Schedule D; but they do not affect a Schedule B assessment.

Estate Duty—The land, and the timber growing on it, are assessed separately. The land pays duty at the agricultural rate, which is 55 per cent. of that appropriate to other forms of property. The timber pays duty at the full rate, but the value of the timber is *disregarded* when fixing the total value of the estate, and hence the full rate applicable to the estate as a whole, is commonly less than it would otherwise be.

The timber is valued at the date of death, and any increase in volume or value thereafter does not attract duty. Payment of duty may, however, be postponed in whole or part until

the timber is actually cut and sold; and allowances made for certain outgoings may prolong this postponement. Should a second death occur before all the duty has been paid, the balance outstanding is cancelled. The property is then re-assessed only in respect of its actual value at the time of the second death.

The land on which coppice or underwood is growing is subject to estate duty, but the underwood crop itself is not.

Local Rates—In England and Wales, no rates are payable on woodlands as such. In Scotland, woodlands are assessed, like agricultural land, at one eighth of the annual rental. But in all the three countries, any sporting rent received from woodlands is rateable at standard values.

LEGAL RESPONSIBILITIES

If a tree growing on land bordering a highway falls and causes damage to passers-by, the landowner may be held liable, but only if it was apparent, to a prudent and observant person, that the tree was dead, diseased or otherwise unsafe, before the accident happened.

Local authorities have powers to remove trees that have blown down across a road, or are otherwise obstructing or endangering passers-by; they may do so without prior notice and are entitled to recover costs from the owner of the trees.

Branches extending over a neighbour's property may be cut back without notice, but only as far as the legal boundary line. The severed branches must be offered to the owner of the tree.

Should the roots of a tree extend on to a neighbour's land and cause damage, the tree owner may be held responsible. The owner may also be held liable if poisonous foliage, such as yew, extends on to a neighbour's field and harms cattle.

Where land is leased for farming, it is the usual practice to reserve " all timber and timber-like trees " to the owner. In the absence of such a clause, local custom may allow a tenant to use timber or underwood, for such purposes as fence repairs or firewood, but only on the leased property.

Bodies possessing special powers with regard to trees, mainly in the interests of keeping open lines of communication include: the Postmaster General (with regard to telegraph

lines); electricity supply undertakings; railways; air navigation authorities; and land drainage boards.

RAISING AND HARVESTING A TREE CROP

Preparing Ground—Land available for tree planting is usually former woodland or scrub, or else ground too steep, broken, rocky or infertile for regular farm use. If ploughing is possible, the opening of furrows every 5 ft. promotes early growth and lessens costs of planting, draining and weeding. The technique of ploughing for afforestation varies according to soil, slope, rainfall, etc., and advice on each job should be sought from the Forestry Commission.

On former woodland or scrub it is seldom wise to remove *all* the remaining tree cover. Scattered trees give shelter from wind, sun and frost, thus encouraging the young crop. They can be removed later without doing much harm, when the new crop is established. Here again, the Forestry Commission can give advice on density and later care. Often the sale of firewood and posts cut from scrub pays for its clearance.

Little is gained by getting a planting site very tidy. Stumps may be ignored and any unsaleable timber or branchwood shifted clear of planting lines. Bracken and weed growth need only be cleared from planting points. The ground must be completely clear of rabbits before fencing it in.

Fencing—Wherever rabbits are found or are likely to reappear, rabbit-proof fencing is essential. It is costly, but economies are possible by making the area as square and as large as can be. The cost per acre is much higher on small, narrow, or irregular sites. Standard rabbit-and-stock proof fences need straining posts, 7 ft. long, 5 in. in diameter, buried 3 ft. in ground and set at corners, gateways or 100 yard intervals. Between these, at least 3 plain galvanised wires, No. 8 gauge, are strained, being set at 18 in., 3 ft. and 3 ft. 6 in. above ground. Stakes 5 ft. 6 in. long, pointed, with 3–4 in. face are driven 2 ft. deep at intervals of 9 ft. The straining wires are secured to these with 1½ in. galvanised staples, No. 8 gauge. Wire netting, 42 in. wide, 1¼ in. mesh, No. 18 gauge, is added to outside of fence stapled to stakes and fastened to straining wires with fine tying wire, giving a height of 36 in. only. The balance of 6 in. is turned out

" towards the rabbits " at ground level and weighted down with sods to stop burrowing. Make sure all gates, stiles and watercourse passages are rabbit-proof. Be ready to tackle the odd pair of rabbits that sneak through.

One chain of fence needs 8 strainers, 200 ft. of No. 8 gauge wire, ½ lb. tying wire, 1 lb. staples, and half a roll of wire netting.

Draining—Trees will not grow where water is stagnant and neglect of drains often leads to windblow. Before re-planting old woodland, open out all old drains. On new ground so site open drains with sloping sides, to collect all water lying in marshy places. Ploughing often improves drainage, but it is usually necessary to link furrows with hand-dug drains in low-lying gulleys.

Plant Supply—Unless a large acreage is to be planted each year, it is not worth while attempting the highly skilled work of raising trees from seed, or even from bought-in seedlings. Good stock can nearly always be bought from nursery-men who charge low wholesale prices for the small trees required for forest use. Seedling trees seldom give good results, and it is best to buy transplants, often described by age as " one-plus-one " or " two-plus-one," according to number of seasons spent in seedbed and transplant line respectively. On open land or ploughed ground, sizes between 6 and 18 inches are satisfactory; in old woodland, where weed growth is heavy, bigger transplants from 12–24 inches high should be used. Prices currently (1957) run from £3 to £8 per thousand according to size and species.

The planting season runs from October to April, but stocks should be ordered well in advance and a date of delivery stated. A hard frost may stop both dispatch of trees and planting; aim to plant early and allow for such delays. When plants arrive, set them with the roots in a trench dug in moist earth until ready to plant. In frosty weather, store in an out-house with straw over their roots; never let roots dry out.

Choice of Species—Once selected, a tree crop cannot be changed for fifty to hundred years, unless it fails completely. Much care should be given, therefore, to the choice of species and local advice is often invaluable. Pure crops, or simple row-by-row or two-row-by-two-row mixtures are

easiest to manage; complex arrangements have no advantages in practice. Coniferous trees, or softwoods, are generally preferable for quick growth and early profit. On some sites broadleaved trees or hardwoods, grow better and give good, if slower, returns. Often it is best to establish broadleaved crops in mixture with a conifer " nurse."

On reasonably fertile, sheltered ground, especially if it be old woodland, a wide choice of species is possible; the deciding factors are likely to be rate of growth and likely uses or markets. On unfertile or exposed land, only one or two species can be expected to thrive; often the vegetation gives a clue to the right choice. On thin soils over chalk, only beech makes good timber; most conifers will shelter it in youth and can be grown to pole size. On heather only pines succeed; spruce fails. On grassy or rushy land with rainfall exceeding 30 inches, spruces are generally the best choice. Japanese larch thrives on bracken-clad slopes; Douglas fir is best kept to old woodlands. For extreme exposure, especially near the sea, stick to Sitka spruce or lodgepole pine. On heavy clays oak is often the only good tree.

Most common timber trees are fully resistant to winter cold; but some suffer setbacks when *late spring frosts* nip tender young shoots. Only those described as *frost-hardy* should be planted in frosty hollows or other spots where cold air flows or gathers on still open nights. *Light-demanding* trees can only be grown in full light. *Shade-bearers* are less exacting in youth and will thrive for some years in partial shade cast by taller trees; often they benefit from such shelter.

CONIFEROUS TREES

Scots pine (*Pinus sylvestris*)—This, our only native timber-producing conifer, is very hardy and thrives in every soil and situation *except* chalk downs, limestone rocks, deep peat or the sea-coast. Grows well on heaths and in regions of low rainfall, particularly in north-east Scotland. Light-demanding; matures at 80–100 years. Not a rapid timber producer, but the timber is well known and easily marketed. Imported " red deal " or " Baltic redwood " comes from this tree and home-grown stuff serves the same purposes. This is the staple softwood for building, fencing, pit props, telegraph

poles, railway sleepers and boxes. Strong, easily worked; not naturally durable but can be treated with preservatives.

Corsican pine (*Pinus nigra* var. *calabrica*)—Satisfactory only in districts of low rainfall and warm summers, mainly in the south and east of the country; good on sand dunes. Grows faster than Scots pine; tolerates sea winds, fairly lime-rich soils and a somewhat smoky atmosphere; is frost hardy and light-demanding. Not easy to establish; use small transplants, planted in mid-winter. Timber resembles Scots pine, but small poles hold more sapwood and are less strong.

Austrian pine (*Pinus nigra* var. *austriaca*)—A coarse tree of little timber value, used only for shelterbelts. Thrives on chalk and resists sea winds.

Lodgepole pine (*Pinus contorta*)—A native of Alaska, this hardy pine thrives far better than others on poor peaty soils and stands exposure from the sea. Is frost-hardy and light-demanding.

Maritime pine (*Pinus pinaster*) and **Monterey pine** (*Pinus radiata*)—Considered hardy only along the south and west coasts, where they are valued for their rapid growth and resistance to salt winds. Planted mainly for shelter. Timber is coarse-grained but serves for fencing, pit props and boxes. Not easy to establish; use seedlings or small transplants.

European larch (*Larix decidua*)—A light-demanding deciduous conifer widely planted on cleared woodland and bracken-clad slopes, where it grows rapidly. Do not plant in frost hollows or severe exposure. Matures at 70–90 years. Larch is not a heavy cropper, but poles are well-liked and readily sold because the heartwood is naturally durable whilst the bark is attractive for rustic work. Used mainly for fencing, gates, garden stakes, rustic poles and pit props; big timber for house and boat building, and estate repairs.

Japanese larch (*Larix leptolepis*)—Now planted on a larger scale than European larch because it grows quicker, tolerates poorer soil and stands more exposure. Small, fast-grown poles may lack the strength of European larch, but older stuff is equally strong and durable and is readily sold for the same uses.

Hybrid larch (*Larix eurolepis*)—A cross between European and Japanese larches that grows more quickly and tolerates poorer conditions than either parent. Seed and planting stock are scarce.

Note—Only the heartwood of larches is durable; where much sapwood is present, it pays to creosote posts, etc. intended for outdoor use.

Douglas fir (*Pseudotsuga taxifolia*)—A beautiful evergreen from British Columbia that can grow faster and give more timber, on ground that suits it, than any other tree. Excellent on old woodland, but unreliable on open ground; light-demanding, frost-tender; matures at 80 years. Timber, imported as " Oregon pine," is very strong, serves the same purposes as Scots pine and is also used for furniture. Not naturally durable, but sapwood takes preservative readily.

Norway spruce (*Picea abies*)—Widely planted because it produces big volumes of timber, but does well only under certain conditions. Thrives in the north and west, where rainfall exceeds forty inches a year; in the drier south and east is only happy where streams or springs provide ample moisture; nevertheless drainage is essential. Likes grassy or rushy ground and is extensively planted on ploughed peats. Dies if planted amid heather. Stands moderate exposure; will not tolerate salt sea winds or smoke. Stands shade and shows some resistance to spring frost. Matures at 70–80 years. Timber, which is just the same as imported " whitewood," enjoys a good demand for pit props, telegraph poles, ladder poles, paper pulp, hardboard, box boards and indoor joinery. Not naturally durable; the heartwood is hard to treat, but the sapwood absorbs preservatives; this means that small poles, being mainly sapwood, can be creosoted to give satisfactory fence posts and rails.

Sitka spruce (*Picea sitchensis*)—Resembles Norway spruce but bears blue-green, sharp-pointed needles. Grows more rapidly and withstands very severe exposure along the coast or on hilltops; likes grassy ground, but is not altogether discouraged by occasional heather; needs ample moisture. Frost-tender and so unsuited to valleys; needs ample light. Timber, imported as " silver spruce " has same properties as Norway spruce.

Note—Both these spruces should be turf-planted or

mound-planted; this gives the best start to their shallow root systems.

Grand Silver Fir (*Abies grandis*)—A tree from British Columbia which has replaced the old European silver fir because it resists insect attack. Best suited to old woodland and established in shelter of other trees. Stands shade. Produces large volumes of a " whitewood " resembling spruce timber.

Western Hemlock (*Tsuga heterophylla*)—Again, a tree that seems most at home in old woodland with some shelter; withstands shade. A beautiful tree of drooping leading shoot; produces a remarkably high volume of good general-purpose softwood. Not naturally durable.

Western red cedar (*Thuja plicata*)—An attractive conifer with fern-like foliage, which stands moderate shade and is well-suited for re-planting cleared woodland, especially if sheltered. Produces straight, strong, light poles with exceptional natural durability; used for fencing, pit props and ladders; the source of cedar-wood roofing shingles.

Lawson cypress (*Chamaecyparis lawsoniana*)—Another conifer with fern-like foliage, best known as a hedge-shrub or garden tree. Grows well on old woodland. Yields a useful, durable timber, heavier and somewhat stronger than western red cedar.

BROADLEAVED TREES

Oak—The two native kinds, pedunculate oak (*Quercus robur*) and sessile oak (*Q. petraea*) are here treated together; intermediate forms are common. Oak has great tolerance of soil and situation, but good timber only grows on deep fertile soils away from severe exposure. As oak is costly to establish, grows slowly and shows little profit from thinnings, it is best kept to such good ground. But on some heavy clays it is the only tree to flourish. Needs 100–150 years to reach maturity. Wood strong and serviceable for all kinds of heavy construction, furniture and fine joinery. Excellent for gate posts, farm fences, gates, and the sills of doors and windows. The heartwood which forms the bulk of any big log, is naturally durable; but small poles contain much perishable sapwood and need creosoting for outdoor use.

Beech (*Fagus sylvatica*)—The best tree to plant on chalk or limestone soils; also does well on fertile well-drained sands or loams. Benefits from the shelter of taller trees or conifer nurses. Stands shade but is frost-tender; resists exposure well, except near sea. Matures at 80–120 years. Produces a strong non-durable timber, which has few uses on the farm, but is readily bought for furniture manufacture; thinnings are saleable to turneries.

Ash (*Fraxinus excelsior*)—Common on most lime-rich soils, but only grows fast enough to yield tough high-grade timber on fertile ground with ample moisture. Matures from 80 years on. Quite small poles are taken by turneries for axe, spade and hammer handles and cart shafts, bigger stuff goes to sawmills for hockey sticks and other sports goods, framing of cars and vans, and furniture. Not naturally durable, but poles are good for fencing, if creosoted.

Sycamore (*Acer pseudoplatanus*)—(Known as " plane " in Scotland). Like ash, an exacting tree that needs moist, fertile, sheltered ground to yield high-quality timber; does well in northern valleys. Matures from 70 years onward. Good logs fetch high prices for furniture and textile mill rollers. Small poles are taken by turneries or may be used, after creosoting, for fencing.

Sweet Chestnut (*Castanea sativa*)—Rarely grown for timber, as logs are subject to splits called " shakes." A valuable coppice crop, cut as poles every twelve years, in the south-east of England where a good market exists for cleft-pale fencing and hop poles.

Hazel (*Corylus avellana*)—Only a bush, but occupies large areas of woodland in the midlands and the south. No longer profitable, except locally for sale to hurdle-makers.

Birch—The two native birches (*Betula pendula* and *B. pubescens*) spring up so freely from wind-blown seeds in neglected woods, that planting is hardly ever done. Short-lived; often fails after 60 years. Hardly worth keeping for timber; better thinned out to allow planting of shade-bearing conifers or, on better ground, beech. Poles can be sold to turneries or used, after creosoting, for fencing.

Alder (*Alnus glutinosa*)—Found only along lakes or water-courses where it renews itself from stump shoots or occasional

seedlings. Seldom planted, but worth keeping as it checks streamside erosion. Poles are harvested every fifteen years or so for turnery or clog soles.

Elms—The field elm (*Ulmus campestris*) and its several varieties is rarely planted in woods, but springs up readily in the hedgerows of fertile lowlands as sucker shoots from the roots of old trees. Saplings are worth preserving when hedges are laid. When full grown and from 70–100 years old, elm is readily saleable to timber merchants for weather-boarding, coffin boards and furniture. It is not durable but it is readily creosoted; it has few farm uses. The wych elm (*Ulmus glabra*) is planted in woods, on good sheltered ground, for its even tougher timber, which is used for furniture and boat building.

Poplars—Grown in a different way to other timber trees, poplars need really fertile, well-watered ground. They are planted as sets, about 6 ft. tall, spaced around twenty-feet apart. Only certain strains of " Black Italian " hybrids are recommended for timber production; *Populus serotina* is the commonest. Pruning of lower branches is essential to limit knots. Poplar matures at only 30 years and logs are then readily saleable to the manufacturers of matches or chip baskets, which are made from thin veneers.

Willows—The cricket bat willow (*Salix alba* var. *caerulea*) requires similar treatment to poplar but matures earlier, at 12 to 15 years, and then fetches a good price from bat-makers. Essential to get right strain and to prune away lower branches.

MANAGEMENT

Planting Distances—The customary planting distance for most forest trees is 5 ft. apart each way, requiring 1750 trees per acre. Sometimes this is decreased to 4½ ft. for pines (2150 per acre) or to 4 ft. for oak (2750 per acre); while on good ground it may be increased to 6 ft. for Douglas fir or Japanese larch (1200 per acre), but variations greater than these are not worthwhile. Poplars and willows are planted at 20 ft. apart (110 per acre).

It is best to order trees for planting at the above rates. Often a small surplus will remain owing to space occupied

by rides, drains, etc. These can be planted out in a corner of the wood or in a garden, set about 9 inches apart, and used next season for filling gaps.

If the ground is ploughed the furrows should run at a distance apart (usually 5 ft.) equal to the spacing adopted. Measuring along each furrow with a spade handle for the right distance (again usually 5 ft.) is sufficiently accurate for the other direction. On unploughed ground a pair of simple sighting rods at each side of the plot enables planters to follow adequately straight lines. When planting shelter-belts or aiming at scenic effects, it is a good plan to "stagger" the rows, placing each tree opposite a gap in the next row; but elsewhere it is hardly worthwhile.

Planting—Notching is the method used for most trees on most soils. It can be done with a garden spade, but a straight-bladed *notching spade* is quicker; on rocky ground a mattock is best. Drive the tool to the full depth of its blade into the earth, then withdraw it and make a second notch at right angles to the first, so that the pattern is shaped either like a letter L or a letter T. Now lever up the ground, so that a crack opens where the two notches meet. Insert the roots of the tree into this crack and draw the tree through until the old ground level mark (or collar) of the tree coincides with the surface of the disturbed ground. Now withdraw the tool and allow both earth and tree to fall back, level with surrounding ground. Finally, stamp everything firm with the heel of the boot.

Turf planting—Generally used for spruces and also for pines on peat. The turf consists either of an upturned piece of sod, about a foot square and from 6 to 9 in. thick, or else the ridge thrown out by a plough. Drive a spade through it, making a cut in one side running *half way* across. Draw the tree into the resulting slit, raising the turf as necessary, and dispose the tree's roots between the two turf layers—one natural, one inverted. Then let the turf fall back, and stamp firm.

Pit planting is only used for poplars, willows and valuable specimen trees. A pit large enough to take the tree roots is dug out with the garden spade. The tree is then held at the right level, with its roots spread as naturally as possible

while the crumbled earth is returned to fall naturally around it; then the earth is stamped firm. Trees of any size require staking when pit planted. Amid grass, a mulch of leaves, cut grass, or farmyard manure will markedly promote growth.

Weeding—In the first years after planting, it is usually necessary to trim back vegetation around young trees which might otherwise choke them. Two or even more such cuttings may be needed each summer, but this is unnecessary once the trees have raised their leading shoots free. Trimming is usually done with a curved reap-hook. A light stick should be carried to push back the weeds before cutting If this is the same length (usually 5 ft.) as the planting distance, it helps the weeder to find small trees as he proceeds down each row.

Cleaning—After trees have grown through the weeding stage, they are best left alone to form a dense thicket. Some 10 to 15 years after planting, this begins to open out near ground level through mutual competition between trees. Often it will then be found—especially on former woodland—that unwanted trees, shrubs and climbers have also established themselves and threaten the welfare of the planted crop. Occasionally, however, good natural seedlings of oak, ash or birch, etc., may have filled gaps and such self-comers are worth preserving. Honeysuckle, traveller's joy, sallow willows and crooked or misshapen stems of other kinds, especially coppice growth from old stumps, should be cut down. This stuff is seldom marketable and is best left to rot.

Brashing—The lower branches of young conifers gradually die but fall so slowly that it is good practice to prune them off to a height of 6 feet, when the crop is 15–20 years old. This work, known as *brashing*, makes it much easier to get into the plantation, to work there and to get stuff out; it saves effort and expense later in trimming poles for sale; it leads to cleaner, less knotty, timber in the bigger stems; and it greatly reduces fire risk. But it seldom pays to prune conifers much above 6 feet. Bill hooks may be used for brashing, but tend to cause wounds; small hand saws and pruning chisels are better; the best all-round tool is a curved pruning saw with a long pole-shaped handle, which enables

both hands to be used together. The pruned branches or *brash*, are just left to rot.

Broadleaved trees do not need brashing; but cricket bat willows should be pruned up to 9 feet, poplars up to 20 feet.

Thinning—As the trees grow taller their crowns expand and more living space for vigorous growth is needed. Hence, it is necessary to thin the crop at intervals, removing the poorer individuals and leaving the better ones to provide big logs of high quality commanding the best prices. If thinning is neglected, only small diameter logs of less worth are produced. The crop also runs more risk of windblow, disease, and insect attack. Worse still, a valuable source of income from the sale of small poles removable as "thinnings" will be lost. Thinnings should begin when the crop is about 20 years old and be repeated every 3–5 years until the crop nears maturity, when ten-year intervals may suffice. In round figures, over nine-tenths of all useful trees normally come out as thinnings. Since they are smaller than final crop trees, thinnings account for about half the volume of timber harvested and one third of the value received. Table 109 shows a reasonable thinning programme for a crop of good quality Scots pine. Broadleaved trees would show lesser yields; but other conifers might give considerably more. This example is based on Forestry Commission *Yield Tables*, which give representative figures for all common conifers. Originally, 2150 trees were planted at a 4½ ft. spacing. By the time thinning began, the crop was 18 years old; 450 young trees had failed and 1700 remained. Thirteen thinnings were carried out as follows:—

The surviving 120 trees then averaged 43 hoppus feet each, giving a total volume of 5160 hoppus feet; if they were left to stand for 5 years more, these figures would go up to 50 and 6000 hoppus feet respectively. The combined yield from thinnings and main crop would thus be 12,070 hoppus feet.

Note how the number of trees removed at each thinning falls from 530 to only 12; but how their individual size increases from 0·26 to 36 hoppus feet Up to the thirty-fifth year the trees thinned out of this crop were only small poles suited to use in the round, as fence stakes or pitprops, or as pulpwood; from the fortieth year onward they were big enough for the sawmills.

TABLE 109

SAMPLE THINNING PROGRAMME FOR A GOOD SCOTS PINE PLANTATION

Age of crop yrs.	Approx. height ft.	No. of Thinnings cut	Average volume Hoppus ft. per stem	Total volume Hoppus ft.	No. of trees left
18	29	530	0·26	140	1,170
21	33½	245	0·7	160	925
25	39½	215	1·5	310	710
30	46½	170	2·8	470	540
35	53	120	4·3	520	420
40	59	85	7·0	600	335
45	64½	65	10·0	630	270
50	70	45	14·0	630	225
55	74½	33	18·0	590	192
60	79	25	22·0	560	167
65	85	20	28·0	560	147
70	86½	15	31·0	470	132
75	89½	12	36·0	430	120
		1580		6070	

Yield tables give a useful guide to the *number* of trees to be taken from each type of crop at each age or stage. To pick the right trees to remove is really a task for a practised forester, but a few hints can be given. Mark all dead, diseased, forked, bent and suppressed trees first; also any very slender ones and any coarse ones that are overbearing a number of better-shaped, if smaller, neighbours. Then see how many otherwise satisfactory trees, suitably spread through the crop, must also come out to bring it to the right density.

Felling—Felling with the axe alone should be restricted to the smallest poles; it wastes too much good butt timber. The bow saw is speedy and satisfactory for thinnings up to one foot thick. For big trees, start by cutting away the butt swelling with the axe; then use the axe again to make the undercut *on the side to which you want the tree to fall.* The floor of this undercut should be close to ground level; it should go about one-third of the way through; and its upper edge should slope at about 45°. Then use a two-man cross-cut felling saw, starting at the side opposite the undercut and a little above its floor. When, as usually happens, the saw jams, drive a wedge in behind it with a sledgehammer (not with an axe-head) and continue sawing. This tilts the tree and

makes it heel over and fall, just before the saw has cut right through. A tree which leans at all, or has heavy branches, is best felled towards the side on which its weight lies. Never fell in a gale, which may bring the tree down in some dangerous, unforeseen direction. Power-driven saws ease the labour of felling, but are barely economic.

Trimming and Cross-cutting—The axe is the best tool for trimming off side branches; a stroke on the *outside* of the branch junction is most effective; a shortened grip often helps. Aim to keep the trunk between the body and the branches being trimmed, as a glancing blow can cause serious wounds.

If the timber is for home use plan in advance the lengths to which each log should be cross-cut; if for sale, consult the purchaser first. The timber trade prefers logs a trifle *over* any stated dimensions, to allow for shrinkage and trimming. The bow saw is best for cross-cutting small logs in small quantities. For a large quantity, it may pay to get a portable motor-driven saw; some types of these can be carried by hand, others work from the tractor power take-off, others again can be towed but have an independent motor. For bigger logs, the two-man hand cross-cut saw is best.

Marketing—The most profitable outlet for poles and timber grown on a farm or estate is generally some use on the property itself; this cuts out a series of merchant's profits and charges and also transport expenses. But usually there is a surplus of material, or it is of some unwanted size or special quality. If an owner has experience of the trade, owns sawing equipment and a lorry, has skilled labour at hand and is prepared to work up a connection with customers, it will probably pay him well to convert his material for sale into some finished form. Otherwise the best course is to sell the timber " in the round " to a merchant. It may be sold " standing " in the woods, or " at stump " after felling, or " at roadside " after hauling out with horse or tractor; the price rising considerably with each step in preparation and transport.

Most reputable timber merchants wish to return in a few years' time to purchase another parcel. They may bargain keenly over price, but will agree to, and observe, all reasonable conditions in the contract of sale. These should include:

dates for entry, final removal of all material and purchaser's equipment, and payment; method of measurement, routes to be used for hauling, repairs to gates, fences, roads or bridges damaged, clearance of lop and top, fire precautions, and arbitration in case of dispute.

If only a small quantity of timber is involved, a sale by private bargain is often satisfactory, but for a large or valuable parcel, it is better to invite several merchants to submit sealed tenders to be opened on a stated date. The vendor should not be bound to accept the lowest or only tender. As a safeguard against letting the stuff go for a price far below its true value, it is often worth while having an independent valuation by a professional adviser. Auction sales are not recommended for small parcels of timber.

Only the most general guide can be given to prices, which fluctuate widely and vary with location. Currently (1957) softwoods range from 1s. for small poles to 5s. for large saw timber; prime oak, ash or sycamore may bring 10s., but small hardwoods fetch no more than small softwoods. These prices are all per Hoppus foot, for trees still standing in the wood.

Conversion of timber on small saw-benches driven by a power take-off is an excellent way of meeting home needs; but such equipment cannot compete, in accuracy of sawing and speed of output, with more specialised plant.

TIMBER MEASURE

The unit of measurement for most round timber in Britain is the Hoppus foot, or cubic foot quarter-girth. It is equal to 1·273 true cubic feet, but it is assumed the surplus of 0·273 is lost to waste when a round log is sawn to squared outline.

Hence the Hoppus foot serves as a measure of possible output of converted timber, though in practice it rarely yields more than nine-tenths of a true cubic foot on the saw-bench.

To find the Hoppus content of a log, measure the length in feet (ignoring odd inches over whole feet or half-feet). Find the mid-point and there measure the girth in inches (ignoring odd fractions over one inch). Divide this result by four to get the *quarter-girth*. Square the quarter-girth (i.e.,

multiply it by itself). Multiply this figure by the length in feet and divide the result by 144.

In practice, a book of tables called a *Hoppus Measurer* is used to show the content for any given length in feet and any given quarter-girth in inches; while a *quarter-girth tape* is used to read quarter-girths direct and so save division by four.

If timber is measured over-bark, an arbitrary deduction, commonly around 10 per cent. is made to get the " under-bark " measure.

Hoppus measure is applied to standing trees as well as felled logs. Here girth is measured at breast-height (4 ft. 3 in.), height is estimated with the aid of tall poles or scientific altimeters and allowance is made for the taper of the tree between breast-height and the mid-point of the useful bole. Only a very experienced man can allow for taper accurately—others will find it better to consult the *Volume Tables* for various trees, issued by the Forestry Commission, which are based on estimated height and quarter-girth as measured at breast height; they automatically allow for taper.

Timber and trees are commonly measured down to a stated minimum dimension, often three inches in top diameter, over bark. Branchwood, unless specially valuable, is ignored.

Converted stuff, such as fence rails, stakes, poles and pit props, are often dealt in by the piece or the foot run. Here, it is essential to specify clearly the minimum top diameter and whether under-bark or over-bark. It helps greatly to know the tolerance, or range of sizes, acceptable. An apparently small increase in top diameter can involve a large increase in volume of timber required to meet the specification. A check on the Hoppus content of sample pieces will show whether a fair price is being offered.

Timber, and even firewood, should never be sold *by weight*, except for prompt dispatch after felling. It loses weight rapidly through seasoning, with every week's delay. For transport purposes it is useful to know that thirty Hoppus feet of fresh-felled timber weigh roughly one ton.

TIMBER PRESERVATION

Little timber is naturally durable when exposed to the alternating wet and dry conditions that favour the growth of wood-rotting fungi. The heartwoods only of oak, sweet

chestnut, larch, western red cedar, Lawson cypress and yew possess natural durability; but small logs of these kinds carry perishable sapwoods and benefit from preservative treatment. In round figures, perishable woods may last for four or five years if used in contact with the ground—e.g., as fence stakes; they will last for thirty or forty years if creosoted and this repays cost of treatment many times over. Creosote is the most widely used wood preservative and is easy to apply. Preservatives containing mineral salts are equally good and cheap, but it is essential to follow the instructions of the makers of proprietary brands very precisely. Tar is of little value. All poles to be treated must first be barked.

Brush application of creosote is satisfactory only on thin boards, up to half an inch thick, which are above ground level and can be reached on both sides, as in a board fence.

Hot-and-Cold steeping is a simple cheap and sound way of treating the butts of fence stakes, gate posts, etc., before erection. Mount a metal drum or similar container over a brick hearth. Insert the post butt end downwards and half-fill the container with creosote. Light a fire below and heat the creosote until it is nearly boiling, i.e., to about 200°. *Then allow the posts to cool in the creosote.* The essential absorption takes place as the heated wood cools and draws creosote deep into its cells. This process may also be applied, by using a larger metal tank and fireplace, to the complete immersion of fencing or building timbers, to give overall protection. Soaking in cold creosote is much less effective.

Pressure Treatment—Treatments involving both heat and pressure need elaborate plant, only worthwhile on a large estate. Deeper penetration and greater protection is obtained and is used for railway sleepers and telegraph poles. Timber can be treated in this way on contract, but is expensive.

Seasoning—This involves storing under cover, or treating in a kiln, to lower the water content. Seasoned timber is much lighter, slightly stronger and less subject to shrinkage or change in shape.

Seasoning is not a preservative treatment—Timber used out of doors on a farm—for example, as fencing—needs little or no seasoning, as it will be continually exposed to damp; but preservative treatment is most important. On

the other hand, timber for use under cover, as in a building, should be well seasoned; but unless it is also to be exposed to damp, as for example, in a window sill, preservative treatment is hardly worth while.

Adequate seasoning for most farm purposes can be achieved by stocking planks or scantlings in a well-ventilated building for at least six months, with small sticks to keep each piece apart and so permit free air circulation.

PROTECTING WOODLANDS

Fire Risk—The danger of fire is always present, but the degree of risk varies greatly. On the average wooded estate, where varied kinds and ages of tree are intermixed and broken up by fields, it is never so high as in a large expanse of young conifer plantations. Everyone owning woods should take simple precautions:—

1. Have available telephone numbers and addresses of fire brigade and police; if in doubt dial 999.
2. Inform fire brigade of location and type of woods.
3. Make sure all parts of woods are accessible for fire fighting; locked gates, broken culverts or fallen trees can all cause delay, allowing minor outbreaks to become major disasters.
4. Have adequate, if simple, fire fighting tools at strategic points; include spades, buckets, axes, bill-hooks and birch brooms. Only birch brooms can safely be left out in the woods; site stacks in full view near gateways.
5. Clear away inflammable vegetation from points of high risk; for example, clear gorse along roads or railways.
6. Brash young conifers early, especially near roads or footpaths.

Few private owners have woods big enough to merit a regular patrol, but in dry weather both owner and woodmen should keep alert for signs of fire. The most dangerous period is from March to May; afternoon and early evening are the most dangerous times of day. Fires may arise at any time when herbage is dry. Woods may be insured against fire, at reasonable premiums, through Lloyd's brokers. If woods

planted under Forestry Commission grants are destroyed by fire, the Commission will consider giving a fresh grant towards the cost of re-planting.

Wind Damage—Avoidance of serious damage by gales is mainly a matter of correct choice of species for site, proper maintenance of drains to prevent soft ground conditions and proper and timely thinning out. With the best of management, however, no forester can stop the occasional gale or gust from bringing down groups of trees. Windblows are rarely a total loss; any tree big enough to be blown down is also big enough to sell.

Insects—Few insect pests become numerous enough to affect management with the following exceptions:—

Pine Weevil—Where a large area of coniferous woods has been felled, burnt, or blown down by wind, the pine weevil, *Hylobius abietis*, which breeds in dead stumps, may increase to plague proportions. It then attacks the bark of young, newly-planted conifers so severely that the whole crop may be destroyed. The most effective remedy is to postpone re-planting for three to four years, to allow the pest to die out. This is not necessary where only small fellings of a few acres, or scattered thinnings have been made through the woods.

Pine Beetle—This is quite a different insect (*Myelophilus piniperda*) which breeds under the bark of felled logs rather than in stumps and attacks the crowns of tall trees, causing defoliation. It does not kill the trees, but checks the growth of the crop severely. Pine beetle is only serious where logs are cut in the summer and allowed to lie in the woods for six weeks or so while the beetle breeds. The remedy is simple—in summer, remove all fresh-felled conifer logs from the woods, or else bark them.

Fungus Diseases—Trees are subject to attack by many kinds of fungi. The most serious from the ordinary grower's point of view are those causing heart rot or butt rot. The fungi concerned, such as *Fomes Annosus*, gain entry to the heartwood of the tree either through some deep wound, such as that caused by the breaking of a branch, or through the roots. They cause decay in the centre of the trunk, which may be slight, or so serious as to make it both dangerous to passers-by and worthless as timber. Unfortunately, only

when infection is well advanced is it revealed by fructifications—toadstools or brackets—usually at the foot of the tree, but sometimes higher up the trunk.

Control of heart rot in hedgerow or woodland trees is impracticable once there is cause to believe trees are affected. Some should be felled and the trunks examined. If rot is prevalent, it may be advisable to clear the crop before sound trees deteriorate in quality and value, but the occasional unsound tree need cause no alarm. Few stands of maturing timber are wholly free of rot, while the timber merchant can usually cut sound lengths of timber from all but the worst-affected logs. As a rule, it is quite safe to replant ground on which heart rot has developed; but where it has been severe it is best to change the kind of tree grown.

MISCELLANEOUS

Shelterbelts—Shelterbelts are woods grown mainly to protect crops or livestock, and under mixed farming systems most belts serve both purposes. The yield of poles and timber from shelterbelts is a lesser consideration. On arable land shelterbelts tend to *depress* yields of crops nearby, because of shading, and the roots draw nourishment from the soil. Increased yields over a much larger area some distance away are noted and, thus, an overall benefit is secured. After allowing for the ground occupied by the belt itself, the increased yield obtained through sheltering moderately exposed land is around 20 per cent. In the case of livestock, shelter often makes the crucial difference between land worth improving and that fit only for rough grazing.

On level ground, a shelterbelt gives appreciable shelter over a distance equal to twenty times its own height; thus a belt sixty feet high will shield a field 400 yards wide. When siting a new belt, advantage should be taken of existing natural features—woods, ridges, etc., to provide a system giving protection from several directions. Belts are best placed at right angles to the prevailing, or most damaging wind, but local features may call for some variation. A belt one chain (66 ft.) wide gives adequate protection. A width of two chains enables one to fell and replant each half-width in turn, but thicker belts do not justify the loss of land occupied. A belt one chain wide holds in practice 12 rows of trees,

spaced 5 feet apart, and 144 trees are needed for every chain of length. The rows should always be "staggered," so as to leave no through gaps.

On hill grazings, shelter blocks, consisting of small square or three-armed plantations of conifers provide useful shelter for stock. The stock move round to the lee side, according to the wind direction, to find ground free from snow.

In determining the right tree to plant the principles set out earlier should be followed—Scots pine on heathery ground, Japanese larch amid bracken, Sitka spruce on grassy peats and beech for chalk downs. Planting and tending methods are similar to those for timber crops, except that shelterbelts should never be brashed, thus allowing the wind through. A very good plan is to site a belt on the lee side of an existing stone wall or hawthorn hedge; the low obstacle shields the shelterbelt trees in youth and serves as a low-level windbreak after the lower branches have died away.

Amenity—Every well-grown tree is a thing of beauty and the best way to secure attractive plantations is to choose the kind of tree suited to the site, tend well and thin out adequately. It is best to "stagger" alternate rows of trees to lessen the straight line effect, to give plantations on prominent hillsides a rounded rather than a sharp-angled outline and avoid making roads or rides running straight up a slope—the easier winding ascent looks less artificial. When the ground permits, planting more than one kind of tree to vary the species occasionally, avoids the monotony of great blocks of one colour and character.

Large, complete woodland clearances should be avoided where possible. A boundary screen of trees left for a while preserves landscape values; it also gives valuable shelter to the new crop.

Hedgerow Trees—Trees along hedgerows have a triple function, providing useful shelter from the elements, preserving scenery and providing an occasional, but appreciable yield of timber. Most hedgerow trees have arisen as chance seedlings or sucker shoots protected from grazing beasts by the surrounding hedge. This is a valuable process that can be continued at no cost simply by looking out for likely shoots, and taking care not to damage them when the hedge is cut

and laid. If trees are planted along hedgerows, more than ordinary care is needed; it is worthwhile choosing big specimens and planting them by the " pit " method. They must be securely protected with individual tree guards, stout and tall enough to check farm livestock, not forgetting sheep, and wired against rabbits.

Trees and Game—Game birds such as pheasants and partridges benefit from good woodland management, for this ensures certain woods—though not of course, always the same woods—are at different stages of growth, thus meeting the varied needs of both birds and sportsmen. Recently felled and newly re-planted woods give open feeding grounds and low cover for nesting; older plantations provide ample safe roosting places; maturing timber leads to high-flying pheasants at shooting time. The aim should be to keep woods at various stages evenly spread over an estate.

Underwood—Coppice or underwood crops are profitable only for a few kinds of tree in a few districts. Sweet chestnut pays well—probably better than any other possible tree or field crop—in districts where cleavers buy it by the acre for fencing. There is far too much hazel available and so prices are low. It usually pays best to replant hazel coppice, after clearance, with a quick-growing conifer that will smother the young coppice shoots, and involve a minimum of weeding; Japanese larch is recommended. Birch coppice, also unprofitable, is best thinned out to one shoot per stump and then underplanted with a shade-bearing tree such as Douglas fir, hemlock or beech. Oak coppice can be partially cleared for firewood and the ground planted with Douglas fir.

Christmas Trees—These are simply young Norway spruce raised at a close spacing on ground of moderate fertility, to heights between 3 and 6 feet. A moist, yet reasonably well-drained rough grass paddock gives suitable conditions; ploughing and turf planting give the trees the best start; use good sturdy transplanted trees about 4 years' old and 2 ft. high; space 2 ft. apart each way, using 10,890 trees per acre. The crop rarely grows evenly, and is best thinned out when some trees reach marketable size, to allow a proportion to grow to the bigger and more valuable dimensions. Ample spacing is needed for large trees, to promote green branches down to ground level. Do not raise Christmas

trees on ground which carries heather or risk the crop near main roads where thefts are easy.

When Norway spruce is ready to thin remember the green tops cut off fetch a good price in late November and early December, but are valueless at any other time of year.

Firewoods—Branchwood from felled broadleaved trees is best used or sold as firewood or charcoal wood; but coniferous timber, even if of small dimensions, commonly fetches a better price for other purposes. A simple portable saw bench driven from the power take-off is adequate for firewood cutting. Oak, ash, birch and beech are excellent firewoods; chestnut burns well, but is apt to spark; alder and elm are poor; poplar very poor. Fruit trees yield good firewood. All the conifers burn well, but larch is apt to spark. Seasoning for a few months, preferably under cover, improves the burning qualities of fresh-felled timber, but by losing water it also loses weight.

AGRICULTURAL LEGISLATION

THE AGRICULTURE ACTS, 1947 AND 1957
THE AGRICULTURAL HOLDINGS ACT, 1948

THE Agriculture Acts, 1947 and 1957, are designed to provide stability for farmers by giving guarantees of price and market, and to provide for efficient production. The Agricultural Holdings Act, 1948, lays down a code of rules regulating the relationship of landlord and tenant in farming.

Guaranteed Prices and Assured Markets—The 1947 Act established on a permanent footing arrangements begun in wartime under which a "review" is held each year between the Government and the National Farmers' Unions of the United Kingdom of the economic conditions and prospects of the farming industry. At each review prices are fixed to apply to the major farm products. The provisions of the 1947 Act were amended by the 1957 Act. Now, the produce qualifying for guarantee as to price and market comprises: (1) Wheat, Barley, Oats, Rye and Potatoes; and (2) Fat Cattle, Fat Sheep, Fat Pigs, Cows' Milk (Liquid), Eggs (Hens and Ducks, in Shell) and Wool. In addition provision is made for a similar guarantee for sugar beet by the Sugar Act, 1956 (replacing provision in the Agriculture Act, 1947).

The guarantees of price and market are now determined for the above commodities for the period immediately following the annual review (held in February) whereas before 1957 the guarantees for crops were related to the harvest of the calendar year following the review.

Provision is also made for the guarantees to operate forward in the sense that there is a limit imposed by the Agriculture Act, 1957, on the extent to which the prices guaranteed in any one year can be reduced in later years. Thus the guaranteed price for any commodity must not be less than 96 per cent. of that fixed at the last annual review; and any reductions in the guaranteed prices for livestock and livestock products must not exceed a total of 9 per cent. in three successive years. Moreover, the 1957 Act provides that the total value of the guarantees and production grants (see below) shall not be less than 97½ per cent. of the previous

year's total, plus or minus any change in costs of production since that time.

The Act contains provision for alteration of the list of commodities guaranteed, and of the percentages above-mentioned. There are safeguards in that before any such change can take place there must be consultation with representatives of producers and affirmative resolutions by both Houses of Parliament.

The 1957 Act also made permanent provision for giving effect to the guarantees, e.g., by payments by the Government to the appropriate marketing Board.

The "price" fixed may be a guaranteed fixed price, a rate of deficiency payment related to a standard price, an acreage payment, or otherwise. Included in the scope of the annual review are also "production grants" as above-mentioned, e.g., for fertilisers, etc. In addition to the annual reviews, a special review may be held as a result of a sudden and substantial change in costs of production. A formula has now been established under which producers have to "carry" until the next review increases in costs to a limited degree, while increases above that limit are not necessarily "recouped" in full (i.e., by increase in prices and production grants).

Good Estate Management and Good Husbandry—The maintenance of efficient standards of estate management and of farming is dealt with by Part II of the 1947 Act (but see note p. 758).

The duty of an owner of agricultural land is to manage the land in accordance with the rules of good estate management. This condition is satisfied when the standard of management of the holding is reasonably adequate to enable the occupier reasonably skilled in husbandry to maintain efficient production in both kinds of produce and the quantity and quality thereof. The law does not insist that the owner shall manage land in the most efficient way possible—his standard must be reasonably adequate to enable efficient production to be secured and in determining the standard, regard must be had to "all relevant circumstances." This means all circumstances affecting management other than the personal circumstances of the owner himself.

The relevant section says that regard must be had to the

extent to which the owner is providing, improving, maintaining and repairing fixed equipment. Whilst the owner can to some extent shift to the occupier, by agreement, his responsibility for maintaining and repairing fixed equipment, the owner remains fully responsible for provision and improvement, and this responsibility cannot be moved.

Fixed equipment includes any buildings or structures on the land, drainage works, farm ditches, hedges and shelterbelts.

The rules of good husbandry require that the occupier must, having regard to the standard of management obtaining, the character and situation of the holding, and other "relevant circumstances" (discussed above) maintain a reasonable standard of efficient production as to type of produce and quality and quantity; and he must also keep the holding in such a condition to enable that standard to be maintained in the future.

After the general statement concerning the principles of good husbandry, the Act specifies that the occupier must (*a*) keep permanent pasture properly mown or grazed and maintained in good fertility and condition; (*b*) keep arable land so cropped to maintain it clean, fertile, and in good condition; (*c*) keep the holding properly stocked, if the farming system involves the keeping of livestock; and maintain efficient standards of management or breeding where stock are kept or bred; (*d*) keep stock and crops free from disease and pest infestation; (*e*) protect and preserve crops harvested or lifted or in course of being dealt with; and (*f*) undertake necessary works of maintenance and repair.

The responsibility for ensuring that reasonable standards of good estate management and of good husbandry are maintained rests primarily upon the County Agricultural Executive Committee. The sanctions are supervision, directions, and, in the last resort, dispossession.

If the C.A.E.C. comes to the conclusion that owner or occupier is not fulfilling his responsibility an order may be made placing that owner or occupier under the supervision of the committee. There is no appeal against the making of such an order, but before it takes effect the person concerned is given the chance of making representations.

The effect of a supervision order is important since anybody properly authorised can enter on the land without notice to see how the person supervised is progressing and the Minister

acquires after a supervision order powers of direction and dispossession.

A supervision order normally lasts for at least 12 months, but if a person under supervision fails to comply with a direction he may be liable for dispossession although 12 months have not passed since the order was made. The case is reviewed at least once every 12 months the order is in force when the person under supervision again has a chance to make representations. Besides this, however, the other party (that is the owner where the tenant is under supervision, or tenant where the owner is under supervision) may also make representations on the annual review and ask the Minister to exercise his powers of dispossession. If the Minister rejects this demand the person making it can take the matter to the Agricultural Land Tribunal; if he grants it the person to be dispossessed can also refer to the Tribunal.

Some directions, relating to fixed equipment can be given without the necessity for a supervision order. These directions relate only to the provision, improvement, maintenance or repair of fixed equipment. Before a direction is served the chance of making representations to the C.A.E.C. has to be given not only to the person in default, but also to the other party, that is the owner or occupier. Generally, there is no right of appeal from a direction, but where the proposal is for the provision of fixed equipment, the owner has a right of appeal to the Tribunal in two cases: (*a*) where the cost of compliance with the direction is substantial (as defined in the Act, Section 15), and (*b*) where the land is subject to compulsory acquisition for non-agricultural purposes.

There are quite severe penalties for failure to comply with the direction when given. Apart from a maximum fine of £100 the Act gives the Minister default powers enabling him to carry out the work and to recover the reasonable cost (to be settled by arbitration).

Directions, following upon a supervision order, can be positive or negative and are not confined to fixed equipment. With respect to an owner they may direct him to entrust the management to a person appointed by him and approved by the Minister. A direction to the tenant may require him to plough up permanent pasture or to carry out other acts of cultivation. The farmer in such cases is protected in complying with the direction in connection with any penalty

under his agreement and for all legal purposes the permanent pasture ploughed up becomes arable land. The owner in this case is given the chance to make representations against the direction and special terms may be prescribed concerning the amount of land to be left under grass on quitting the holding at the end of the tenancy.

The final penalty for failure to comply with the rules of good estate management, or the rules of good husbandry, is dispossession. Dispossession is always preceded by a supervision order and save in one instance that order must have been in existence for at least 12 months. The exception is where the person under supervision fails to comply with a direction.

Assuming it is the owner under supervision for bad estate management and the Minister is not satisfied he is improving, when the whole or any part of the land to which the supervision order relates can be compulsorily purchased. At any time before compulsory purchase takes effect the owner can dispose of the land, although this does not automatically revoke the supervision order. Again, an owner wishing to resist a proposal for dispossession can, if he chooses, ask the Minister to approve of a proposal to entrust the management to somebody else and to give a direction accordingly. The owner has the right to make representations to the C.A.E.C. against a proposal for dispossession.

If, in spite of these representations, however, the order is made, the matter can be referred to the Agricultural Land Tribunal. If the proposal to make the order for dispossession is confirmed, the Minister acquires the land compulsorily and pays as compensation the amount which would be paid by any other public authority on a compulsory acquisition.

In the case of a tenant under supervision, the Minister, if satisfied that the farm has not shown satisfactory improvement under supervision, can terminate the tenant's interest in the land as from a period not less than three months from the date of the dispossession order. That order can require the owner either to farm the land himself or to let it to a tenant approved by the Minister. In the case of an owner-occupier under supervision for bad husbandry, the dispossession order may direct the owner-occupier to give up occupation at a date not earlier than three months from the

time of making the order and to let the farm to a tenant approved by the Minister.

In the case of dispossession for bad husbandry, therefore, the owner-occupier has to let the farm to a tenant approved by the Minister, or where the dispossession is of a tenant the owner has to farm the land himself or again let it to an approved tenant. The Act also states that if no arrangements satisfactory to the Minister are made under this provision the Minister (that is the C.A.E.C.) can take possession of the land for the purpose of farming it when either the land will be farmed direct by the C.A.E.C. or let by them to a private person similarly placed to a tenant having possession on the basis of a contract with the C.A.E.C. The Act further contemplates that in the last-mentioned case the arrangement terminates if and when the owner enters into a tenancy agreement direct with the private person who contracted with the C.A.E.C. for the farming of the land.

Although after 1947 many cases of supervision and dispossession arose, the numbers steadily decreased after 1950, and by 1957 it was clear that these sanctions would only be imposed in exceptional circumstances.*

Agricultural Holdings—The law relating to agricultural holdings is now embodied in the Agricultural Holdings Act, 1948. The Act provides a new definition of "agricultural holding," that is, the aggregate of the agricultural land comprised in a contract of tenancy. For all practical purposes the 364-day tenancy is abolished. Unless the prior consent of the C.A.E.C. is obtained in a given case, all 364-day tenancies are to be treated as yearly tenancies except in the case of land let or licensed for part of a year for mowing or grazing.

Provision is made to ensure that either party can insist that the tenancy agreement involved is in writing, and that written agreements cover all the important points such as liability for outgoings, covenants for replacement of assets damaged or destroyed by fire, and for insurance. Therefore, where an agreement is oral or if in writing does not cover all the

* Moreover, at the opening in November, 1957, of the 1957/8 Parliamentary session, the Government announced that legislation was in contemplation to remove the "disciplinary powers" of the 1947 Act, to amend the law concerning security of tenure, and possibly also to remove all judicial powers from C.A.E.C.s, giving the latter directly to Agricultural Land Tribunals.

cardinal points, either party may ask the arbitrator to commit to writing the actual agreement of the parties.

A new power was given to the Minister by the Act to prescribe a statutory clause as to maintenance, repair and insurance of fixed equipment. The Minister has in fact exercised this power, and has prescribed the clause by Regulations. This divides responsibility for maintenance and repair by giving certain tasks to the landlord and others to the tenant. The landlord's tasks are mainly concerned with exterior works and works of a structural character, whereas the tenant has to undertake interior work and other matters closely connected with actual farming operations, such as hedging and ditching.

The clause will not, however, apply in so far as specific provisions on the same subject are included in existing written agreements. But if an agreement, old or new, does make specific provision substantially departing from the statutory clause, either side may ask the arbitrator to consider variation of the terms.

Either party to a tenancy agreement can under the Act, on giving notice to the other party, demand arbitration on rent. This does not apply to a lease for a period of years. Once fixed by agreement, or by the arbitrator, the rent stands for at least three years before an arbitrator can be asked to consider the matter again, unless an increase in rent is proposed as a result of improvements carried out under statutory direction or provision.

The terms of an agreement relating to permanent pasture may also be varied by the Minister in the interests of efficient farming. The Act contains complicated provisions to this end. These enable a person given a direction to plough up permanent pasture to be exempted from any liability in respect of that action and conditions may be made concerning the amount of pasture to be left on quitting (not to exceed the original amount specified in the agreement). Conditions may also be made on the amount of compensation due to the tenant for pasture so left.

Under earlier legislation the tenant had certain rights with respect to disposal of produce and freedom of cropping of arable land. These rights remain substantially unaltered in the 1948 Act as also the tenant's right to retain and remove tenant's fixtures and buildings, but notice by the tenant of

the proposed removal of a fixture or building must be given at least one month before the termination of the tenancy; the right to remove is not exercisable after two months have elapsed from the termination of the tenancy.

Notice to Quit—In connection with notice to quit, the old law has been substantially altered. In the first place the rule that at least 12 months' notice to quit an agricultural holding must be given, to expire at the end of a tenancy year, is preserved; and this general rule now applies equally to notice to quit part of a holding (where such a notice can be validly given). But the 1948 Act includes certain provisions, the object of which is to give the good tenant security of tenure by placing restrictions on the validity of notices to quit served by a landlord. When such a notice to quit is given the tenant can, within a month, serve a counter notice demanding the consent of the Minister. If he does not serve this counter notice consent is not required to make the notice to quit valid. Nor can the Minister's consent be demanded in cases in which the landlord would not be liable for compensation for disturbance or where the land is required for some approved non-agricultural purpose.

The over-riding principle of this consent provision is that the Minister must refuse consent unless he is satisfied on at least one of five points. Even if so satisfied he can still withhold consent or impose conditions upon granting it. Briefly the five points are:—

(*a*) that notice is given for a purpose desirable in the interests of efficient farming; (*b*) that it is desirable in the interests of research, education, experiment or of the provision of smallholdings; (*c*) that the tenancy began after 5th August, 1947, and that possession is required for a purpose specified in the agreement, and that greater hardship would be caused by refusal than by consent; (*d*) that in the case where the tenancy was created before 6th August, 1947, and there has been no change in landlord between that date and service of notice to quit or application for consent, greater hardship would result from refusal than from consent; and (*e*) that there is to be an approved change to non-agricultural use. (See footnote page 758.)

In all cases of proposal to grant or refuse consent to the notice to quit the parties concerned can make representations

to the C.A.E.C. and may appeal from the C.A.E.C.'s conclusion to the Tribunal.

Provision is also made by the Act for the case in which the holding is agreed to be sold during the currency of a notice to quit, in effect giving the tenant an option to treat the notice as good or bad.

Compensation for Disturbance—The new law makes no serious change in connection with compensation for disturbance—which is still based on loss or expense sustained by the tenant being not more than one year's rent nor more than two. As before, the right to this compensation is excluded by bad husbandry, failure to pay rent or to remedy some other breach of covenant, bankruptcy, or death of the tenant within three months prior to the notice to quit.

Of bad husbandry it should be noted that the certificate must be obtained before the notice to quit is served. Application for the certificate of bad husbandry has now to be made to the Minister and no certificate is issued while a supervision order is in force. Instead of granting such a certificate the Minister can make a supervision order. An appeal may be made to the Tribunal against any decision to grant or refuse a certificate but not against a decision to make a supervision order; accordingly an arbitrator is no longer involved in this matter. (See footnote p. 758.)

Compensation for Improvements—It should first be clearly understood that the law with respect to compensation for improvements begun before 1st March, 1948, remains unaltered. Accordingly, the position of outgoing tenants in connection with compensation for improvements will in respect of all those begun before that date be governed by the old law, that is the Agricultural Holdings Act, 1923. New provisions are, however, made in respect of improvements begun on or after 1st March, 1948, and in respect of tenant right matters.

New improvements are now divided into "long term" set out in the Third Schedule to the 1948 Act and "medium term" set out in Part I of the Fourth Schedule. The long-term improvements are themselves divided into two groups, that is (*a*) those of such substance as might alter the character of the holding; as to these the landlord's consent must be obtained if compensation is to be claimed; and (*b*) those

which would not have the same effect, in respect of which, therefore, either the consent of the landlord or of the Minister may be given. An example of an improvement which must have the landlord's consent if compensation is to be claimed is the making of works of irrigation; the principal example of improvements in respect of which either the consent of the landlord or of the Minister must be obtained to preserve title to compensation is the erection, alteration or enlargement of buildings.

Where the landlord in the latter case refuses consent the tenant can approach the Minister (C.A.E.C.). After hearing both parties the committee may give consent, in which case the landlord is given the chance of doing the improvement himself.

The medium-term improvements set out in Part I of the Fourth Schedule require no consent, but notice to the landlord must be given in respect of any plans to carry out mole drainage works (which come within Part I of the Fourth Schedule).

The making of watercress beds is added as a long-term improvement, requiring the landlord's consent whilst the provision of electric light or power, means of sewage disposal, and the growing of herbage crops for commercial seed production now appear in the group requiring the consent of the landlord or the Minister.

Land drainage generally (which previously required notice only) now requires the consent of the landlord or Minister; notice only is needed for mole drainage, the latter being the only improvement appearing in Part I of the Fourth Schedule for which notice is necessary. The old items appearing in the Schedule of improvements in the 1923 Act are reproduced with alterations, some of which are important. For example, folded poultry are brought in with horses, cattle, sheep and pigs, in relation to consumption of feeding-stuffs not produced on the holding.

The list of improvements may be varied by the Minister by regulation; but this can only be done after consultation with bodies representing landlords and tenants, and any Order making a variation requires affirmative resolution of both Houses of Parliament.

It should also be observed that in respect of improvements begun on or after 1st March, 1948, compensation may be

claimed even though such improvements were carried out in the last year of the tenancy.

Mention should be made of the measure of compensation. While as before, in regard to medium-term improvements and tenant right, the measure is based upon the value to an incoming tenant, the new basis for long-term improvements is in effect a capitalisation of the increased rental value due to the improvement. With long-term improvements, the parties can come to an agreement, varying this basis, but no contracting out is permitted with respect to the measure of compensation for medium-term improvements.

Tenant Right—In this field also an important change was made. The 1948 Act lays down that, apart from existing tenancies, the out-going tenant can no longer base his claim upon the custom of the country but will instead claim compensation on the basis of the value to an incoming tenant by virtue of the Act. The method of calculating valuations has been reported upon by an expert committee, including representatives of all interests in the industry, and this forms the basis of settlement of tenant right claims. It is, however, always open to the parties by written tenancy agreement to deal with tenant right in whatever manner they wish, for example, by substituting a different measure of compensation from that laid down in the Act, and the Act also provides that with tenancies existing on 1st March, 1948, the tenant can elect (and be made to elect before he leaves) whether he wishes to go out on the old basis or on the new one which the Act provides.

Statutory provision is also made for compensation for high farming and conversely for dilapidations. Finally, the system of settlement of claims by arbitration is preserved and extended by the 1948 Act and all claims between landlord and tenant arising on or out of the termination of the tenancy are to be referred to arbitration under the 1923 Act procedure.

Smallholdings—Part IV of the Agriculture Act, 1947, deals exclusively with smallholdings, and provides the statutory framework for a new Government policy for the provision of smallholdings. This part of the Act extends only to England and Wales and came into operation on 1st October, 1949.

The principal feature of the new policy is that only a person possessing sufficient agricultural experience to make it likely that he is, or is likely to become, qualified to be a farmer on his own account will be considered as an applicant for a smallholding, the main objective being to provide a ladder of opportunity for such persons with limited capital to acquire independence in agriculture. In short the present policy may be contrasted with that obtaining in the past in that formerly the prime considerations were of a social character designed to assist the settlement of ex-servicemen and unemployed from industry on the land, whereas now the objective is the provision of a career for agricultural workers and others concerned with agriculture in a like economic position.

The duty to provide smallholdings is imposed by the Act upon every county council (except the London County Council) wherever there is a demand therefor in the county. These councils, known for this purpose as smallholdings authorities, are given the power to acquire land to provide smallholdings, either by agreement or compulsorily, subject to the Minister's approval. The smallholdings authority provides and maintains fixed equipment on the holdings, but in the absence of any general directions given by the Minister an authority can only proceed to establish and equip smallholdings in accordance with a scheme submitted to and approved by the Minister.

As to finance, the Minister may contribute up to 75 per cent. of any estimated loss anticipated by a smallholdings authority in connection with a proposed scheme, and detailed provision is made for keeping accounts for this purpose. Smallholdings authorities have no power to sell holdings to their tenants, thereby preventing any decrease in the amount of land available for letting to a succession of smallholding tenants. The tenants themselves may, under the Act, be provided with working capital by loans of an amount up to 75 per cent. of the estimated aggregate working capital required.

The powers of county councils in connection with smallholdings are exercised through smallholdings committees. The majority of members of these committees consist of members of the council but other persons may be appointed to serve; in particular arrangements are made for an officer

of the Minister, normally the Land Commissioner, to be present at meetings of the smallholdings committee.

A smallholding is defined by the Act as a holding of more than one but not more than 30 acres, or between 50 and 75 acres, provided in the latter case that the full fair rent does not exceed £150. In every case the holding must be let at a " full fair rent," that is a rent such as a tenant might reasonably be expected to pay for the holding as such and on the terms on which it is in fact let.

Quite apart from the 1947 Act the Minister has set up a Smallholdings Advisory Council. This council published its first report on 11th March, 1949, giving recommendations on administration of smallholdings and summarising the history of the subject and the effect of the new law.

Administration—Under Part V of the 1947 Act the necessary provision is made for administration of the new law established by the earlier parts of the Act. Three new bodies are set up on a statutory basis.

The first is the Agricultural Land Commission having the function to manage and farm land vested in the Minister and to advise the Minister on problems of management. The Commission is a small body of persons directly appointed by the Minister. It has no power to buy or sell land but may let holdings (which are in State ownership) on yearly tenancies. A separate sub-commission for Wales and Monmouthshire was also established under the Act. The Commissions are mainly concerned with matters of general policy and other specific functions given to them under the Act, whereas all the " field work " is done through the County Agricultural Executive Committees and the Agricultural Land Service.

These C.A.E. Committees set up by this part of the Act consist of 12 members, seven of whom are " nominated members " appointed by the Minister from panels submitted by the organisations representing farmers, owners and workers. The other five members are directly appointed by the Minister and include one member of the appropriate county council and persons having special knowledge or experience.

The C.A.E.C. act through sub-committees and district committees. The district committees have powers of report

and recommendation only, but executive power may be delegated to a sub-committee. In fact, the C.A.E.C.'s with their sub-committees and district committees administer most of the provisions of Part II of the Act relating to good estate management and good husbandry.

The third new body set up for purposes of administration is the Agricultural Land Tribunal concerned in connection with a number of matters to hear appeals against decisions which affect the owner or occupier of agricultural land. The decision of the Tribunal in any particular case is final. The chairman is a lawyer and the other two members of the Tribunal are selected from panels representative of owners and farmers. The procedure of the Tribunal is worked out in detail in special Regulations (see footnote page 758).

Acquisition of Land—Wide powers are given to the Minister to acquire or hire compulsorily or by agreement agricultural land for various purposes. These include the powers to acquire land where the Minister considers that full and efficient use is prevented because work is not being done or equipment is not being provided or maintained. In this special case the matter is referred to the Agricultural Land Commission for investigation and report and opportunity is given to the parties concerned to state their case before a decision is reached.

The Act also deals with cases where the Minister is in possession of land under war-time powers in respect of which he may exercise powers of compulsory acquisition instead of returning it to the person from whom it was requisitioned. If the Minister decided to acquire, any person interested in the land can appeal to the Tribunal.

Reference should also be made to a new provision enabling the Agricultural Land Commission to carry out a limited number of experimental schemes for re-adjustment of farm boundaries. The first experiment of this kind was undertaken by the Commission in respect of land at Yetminster, Dorset. Another power to acquire land compulsorily is conferred by the Act for the purpose of preventing the breaking up of farm units into uneconomic parts.

Wherever compulsory purchase takes place as a result of the exercise of powers under the Act, compensation is paid at the full "existing use value," that is, the current market value for agricultural purposes. There is also power for

land to be hired by the State, but where this is done the limit of the hiring is a term of 35 years.

In practice the Minister's powers to acquire land are exercised only in exceptional circumstances. The policy of the Government was revised considerably after public feeling had been aroused by the " Crichel Down " case.

Finally the 1957 Act makes provision for a scheme of capital grants for long-term improvements of farming land. A detailed schedule of types of improvement eligible for grant is appended to the Act, and the rate of grant is one-third of the approved cost.

TOWN AND COUNTRY PLANNING ACTS, 1947-1954

These Acts made a fundamental change in the rights attaching to ownership and possession of land.

Planning Control—The object and effect of the 1947 Act was to control the manner in which every piece of land in the country is used. Planning authorities are constituted by the Act in order to exercise control; these authorities are every county council and county borough council, and authorities may combine to constitute joint planning authorities.

The Act provided that by the 1st July, 1951, every planning authority should prepare a development plan for submission to the Minister (now the Minister of Housing and Local Government) showing in outline the use to be made of all land in the area covered by the authority. Areas were to be earmarked for agriculture, industrial development, housing, green belts, and so on. In practice very few plans were submitted by the 1st July, 1951, but were put in later.

The submission of the plan to the Minister had to be advertised in the local press indicating where the plan could be inspected and how objections could be submitted. Any person could record an objection to the plan, which must be considered by the Minister. Ultimately the Minister confirmed the plan with or without alteration, but before doing so an oral hearing had to be given to all who had objected—usually at a public local inquiry.

Under the Act land cannot be " developed " without the consent of the planning authority for the area. " Develop " is a technical term and broadly speaking covers the building

upon or mining of land or the change of the use to which land or buildings are being put. A man " develops " his land if he builds a house on it, digs gravel, or converts a house into an hotel.

If the planning authority grant permission for development they may attach conditions. They may, for example, require the design of any building to conform to certain standards. But if the authority refuse permission to develop, or grant permission subject to conditions which the developer is not prepared to accept, he may appeal to the Minister. This appeal has to be lodged within one month of the receipt of the authority's notification that planning permission has been granted or refused. There is no right of appeal from the Minister's decision. If the applicant can show, however, that the land is incapable of " reasonably beneficial use " if he uses it only in the way which the planning authority is prepared to allow, he may demand that the local authority shall buy the land. The decision on this question rests again with the Minister. In some cases a developer who is refused permission can claim payment of compensation.

A development plan may indicated areas which the planning authority consider will eventually have to be acquired by the State or a public authority. If and when the time comes for such acquisition the usual procedure (if the acquisition is compulsory) will be followed. In practice, however, it is necessary for the objector to make sure that his objection to compulsory acquisition is made at the time when the development plan is prepared and published since a later objection may be disregarded if, in substance, it amounts to an objection to the plan already approved.

The Act empowers the Minister to permit generally (and without any special application) certain specified types of development by Order. Such an Order called the Town and Country Planning (General Development Order), 1950, was made on the 8th May, 1950, and came into force on the 22nd May, 1950. This is of great importance to agriculture. Under this Order the owner or occupier can carry out on agricultural land, having an area of more than one acre and comprised in an agricultural unit, any building or engineering operations requisite for the use of the land for the purposes of agriculture, other than the placing on land of structures not designed for those purposes, or the provision and alteration

of dwellings. Thus farm buildings necessary for agricultural purposes can normally be erected without applying for planning permission unless they are sited near an aerodrome or a public road. Planning permission must be obtained, however, before a dwelling house, be it farmhouse or worker's cottage, can be built.

Special considerations apply to agricultural holdings within certain National Park areas, e.g., Snowdonia, the Lakes and the Peak District. In these cases the general permission given by the Order mentioned above will not apply and before erecting, altering or extending an immoveable structure, 14 days' written notice must be given to the local planning authority together with a short description of the proposed building, the materials to be used and a site plan. If the local planning authority do nothing within 14 days, the developer may go ahead; but they may in that period require prior approval to the design and external appearance of the building before any development is begun.

It should be carefully noted that exemption from planning permission under the Act—or indeed the granting of planning permission—does not give exemption from building by-laws or other requirements not connected with planning for which the local authority should be consulted.

Application for planning permission under the Act is made on a form obtained from the district council. The application with accompanying plans (as specified on the form) is submitted to the district council, which passes them to the planning authority. A decision must generally be reached and the applicant notified within two months. If a decision is not received within this time, the application is deemed to be refused when an appeal to the Minister should be made without waiting for any further communication from the planning authority.

Claims for compensation for loss of development value—When the 1947 Act was passed the Government of the day took the view, which was embodied in the Act, that the landowner who lost development value had no right to compensation for his loss; but a sum of £300 million was set aside out of which compensation could be paid to such owners. Any owner who claimed that he had sustained such a loss had to submit his claim by the 30th June, 1949. When the

claims were lodged, a scheme was to be drawn up by the Treasury for payment or division of the fund amongst claimants; and the Act provided that payments of compensation were to be made in negotiable Government Stock in July, 1953.

The Town and Country Planning Acts, 1953 and 1954, made very drastic changes in these arrangements, but it is a mistake to think that they meant anything like a return to the conditions with respect to sale of land for development (apart from planning control) which existed before the 1947 Act was passed. The essential thread of principle running through the Acts is that the Government will only recognise for compensation purposes, development value which had accrued in respect of any given area of land, by the 1st July, 1948, and which is the subject of a claim already admitted against the £300 million fund. In other words, development value, as it were, "crystallised" on that date and any further accretions (or reduction) in development value of a particular piece of land since that time is irrelevant to any claim for compensation on acquisition, or for refusal of permission to develop.

The new Acts abolished the £300 million fund and there was, therefore, no general distribution of compensation as was laid down by the 1947 Act.

Instead compensation is paid for loss of development value in individual instances as and when they occur, as well as in respect of cases which have arisen since the 1947 Act came into force. The cases in which compensation may be payable will be either those in which land is acquired, or those in which planning permission is refused or restrictions imposed.

Where land has been compulsorily acquired since the 1947 Act became law, the compensation payable was based upon the "existing use value" of the land without any addition for loss of development value. But now there will be in addition compensation paid for the loss of development value to the extent that there is or might have been an admitted claim on the £300 million fund already in existence. Again if a landowner is refused permission to develop on planning grounds he may be entitled to claim compensation in respect of that refusal, but only to the extent of any admitted claim for loss of development value. Similarly

such compensation will be payable in respect of certain planning restrictions on development.

Apart from compulsory acquisition sales of land in future will take place at market value. This will, of course, be affected by planning permission, but subject thereto the price of land should include its full development value. The Government sounded, however, a note of warning here in that they recalled that local authorities have powers to buy land compulsorily in order to make it available to private developers, if for instance a landowner were to hold out for an unreasonable price and the building or development was something which the public badly needed and for which planning permission had been given.

To sum up, the theory underlying the new legislation is that the landowner will have the advantage of a "free market" on sale of his land in the sense that he can ask whatever price he thinks appropriate, subject to the effect thereon of planning control and to the note of warning sounded by the Government about action by public authorities. But so far as the Government is concerned they will only recognise the title of the landowner to development value so far as this had accrued on the 1st July, 1948, and is the subject of an admitted claim for compensation.

AGRICULTURAL MARKETING ACTS

The first Agricultural Marketing Act became law at the end of July, 1931. It had the distinction of being annotated in a Report which was published as an Orange Book in the Ministry of Agriculture's Economic Series. The Report contended that large scale organisations were daily becoming more necessary, alike for those commodities mainly affected by internal competition and for those particularly subject also to the competition of imports. "The task of forming such organisations on voluntary lines would be formidable," it proceeded. "The task of holding together such organisations, even if formed, would be still more formidable so long as a minority of producers could stand by and leave to others the obligations and responsibilities which should, in fairness, be borne by all. Unity of plan and unity of execution connote discipline of the whole and not merely of a part."

That was the situation which the 1931 Act was designed to meet. Of schemes under the Act the Report declared

that "democratic control in the administration of every scheme is assured by the fact that the board, i.e., the administrative body entrusted with the administration of the scheme, is composed of the elected representatives of registered producers."

The Hops Marketing Board was the first to come into existence, followed by Boards to handle milk, bacon pigs and potatoes. Provision for the control of imports was embodied in the Agricultural Marketing Act of 1933.

The main features of the Marketing Acts are summarised below:—

Agricultural Marketing Act, 1931—The Act enables a scheme regulating the marketing of an agricultural or horticultural product by its producers to be submitted to the Minister of Agriculture for his approval. ("Product" includes articles of food or drink wholly or partly manufactured or derived from it, as well as fleeces and the skins of animals.) The scheme may apply to the whole or any part of Great Britain. The power to submit schemes is in the hands of the producers of the products in the areas concerned. The persons submitting the scheme must satisfy the Minister that they are substantially representative of the producers of the product concerned in the area to which the scheme is applicable.

The Minister's first task after the scheme has been submitted is to "Gazette" it, i.e., publish notice of the scheme, and give information about where copies may be obtained. The notice must also specify a period—not less than 6 weeks—in which objections and representations may be made in respect of the scheme. Any objection must be in writing, specifying the grounds of the objection and the specific modifications in the scheme which the objector seeks. The objections are considered by the Minister, and if they are persisted in, the Minister institutes a public enquiry by a competent and impartial person.

The Minister then considers the report of the enquiry and all other relevant factors, and decides whether the scheme should proceed, i.e., if satisfied that the scheme will conduce to the more efficient production and marketing of the regulated product; and if so, whether any modifications should be made therein. He must give notice of any such modifica-

tions to the nominees of the "sponsors"—the persons submitting the scheme; and unless these nominees, or the majority of them, accept the modifications within 4 weeks or such further time as the Minister allows, the Minister can take no further action and the scheme will lapse.

If the modifications are accepted, the Minister submits the scheme to Parliament for the affirmative resolution of both Houses, i.e., express approval is required. Then the Minister makes an order confirming approval, which means that the proceedings cannot thereafter be challenged on grounds of any technical defect.

The scheme then comes into force, for the "suspensory period," from a date specified by the Minister's order. The initiative now passes back to the producers. The main duty during the suspensory period (during which the only operative provisions of the scheme are those relating to the initial poll) is the conduct by the new Board of that poll.

For this purpose the first task is the compilation of a register of those entitled to vote. Accordingly the Minister's order of approval of the scheme is widely advertised by him; and he must furnish to the Board such information as he has concerning the names and addresses of the registered producers in question. The Board also have to advertise, and to send all addresses in the Minister's list a form of application for registration, and other details, so that the poll gets as much publicity as possible and all reasonable steps are taken to inform producers about it.

The way in which the initial poll is conducted must be prescribed in the scheme and therefore approved by the Minister, but the Act lays down certain rules about it. For the scheme to become effective there must always be a majority in favour of two-thirds of those voting in terms of numbers and output. Steps must be taken to secure the proper conduct of the poll, and the method of declaring and publishing the result must be prescribed by the scheme.

If the poll is favourable, the scheme still does not come fully into operation at once. There must be an interval between the declaration of the poll, and the coming into effect of the scheme, prescribed by the scheme but not being less than 1 month or more than 2 months. During this interval, any person may week to prove to the Minister that at the poll less than half the total number of producers

affected by the scheme (apart from exempted producers) voted. If he succeeds in proving this, the Minister must revoke the scheme. Otherwise on the expiry of the interval the scheme comes fully into effect.

There are various provisions which must be embodied in schemes. These include:—

Prohibition of sales of the regulated product by producers who are not registered or exempted.

Exemption by the Board of producers and sales of specified classes or descriptions of the regulated product.

Provision for establishment of any market or slaughter-house if desired by the Board.

There are other provisions which may be embodied in schemes. These include:—

Power to buy, sell, grade, pack, store, adapt for sale, insure, advertise, and transport the regulated product.

Power to require registered producers to sell the regulated product only through the agency of the Board.

Power to determine the kind, variety or grade of the regulated product which may be sold; fix maximum and minimum prices, and to whom, and on what terms, the product may be sold.

Power to regulate the grading, marking, packing, etc., of the regulated product.

Inspection of the land and premises of producers.

Encouragement of agricultural co-operation, research and education.

Types of Schemes—The Act provides for three main kinds of organisation, viz.: (i) a trading Board which buys and sells the regulated product or acts as sole agent for its sale, and may engage in manufacturing commodities from the regulated product; (ii) a regulating Board with the sole duty of giving instructions as to the methods and operations to be adopted in marketing the regulated product; and (iii) a Board exercising both trading and regulatory functions.

Provision is made for "Substitutional Schemes," i.e., schemes revoking and replacing one or more existing schemes and providing for the registration of the same producers as were affected by the previous scheme or schemes.

Agricultural Marketing Funds—The Act requires Agricultural Marketing Funds to be established for England

and Scotland from which loans may be made to Boards. The English Fund is controlled by the Minister of Agriculture.

AGRICULTURAL MARKETING ACT, 1933

Regulation of Imports—This Act empowers the Board of Trade, after consultation with the Minister of Agriculture and the Secretaries of State concerned with agriculture in Scotland and Northern Ireland, to make orders regulating the importation of agricultural products into the U.K. The making of orders is dependent upon the Board being satisfied that all practicable and necessary steps have been, or are being, taken to reorganise under marketing schemes the branches of U.K. agriculture concerned and that their reorganisation and development cannot be achieved or maintained without such orders. Imports may be regulated by determining for any specified period the quantity of the product and the descriptions of the product which may be imported.

The Board of Trade must have regard to the interests of consumers of the product concerned and to the likely effect of an order on commercial relations between the U.K. and other countries. The Board must also be satisfied that an order would not conflict with any treaty, convention or agreement with any other country. Where the importation of an agricultural product is regulated by an order and the Board of Trade certify that arrangements have been made for controlling such importation, the above-mentioned Agricultural Ministers, if they are satisfied that it will promote the efficient reorganisation or organised development of any branch of U.K. agriculture or necessary to secure its economic stability, may make an order regulating sales of the product by persons producing it in the U.K. or by Agricultural Marketing Boards by determining for any specific period the descriptions and quantity of the product which may be sold. Before an order is made, the Board of Trade, the Market Supply Committee and any Marketing Boards concerned must be consulted. The above-mentioned Agricultural Ministers were required to set up a Market Supply Committee for the U.K., but this provision was repealed by the 1949 Act.

Development Schemes—The Second Part of the Act dealt with Development Schemes, but these provisions were repealed by the 1949 Act.

AGRICULTURAL MARKETING (No. 2) ACT, 1933

The powers of Marketing Boards to purchase and deal with products were extended so that a scheme may provide for empowering a Board (*a*) to buy from another Board administering any corresponding scheme any product the marketing of which is regulated thereunder; (*b*) to produce from any purchased product any commodity which the Board are authorised to produce; (*c*) to sell, grade, pack, store, adapt for sale, insure, advertise and transport any purchased product or commodity produced therefrom; and (*d*) to exercise as agents for the Board administering a corresponding scheme any power of that Board to deal in any manner mentioned in (*c*) with any product controlled by the corresponding scheme.

THE AGRICULTURAL MARKETING ACT, 1949

Composition of Boards—The old law with respect to composition of a marketing board was comprised in Section 14 of the 1933 Act; that section contained no upper limit of members. Under Section 1 of the 1949 Act the strength of the Board must be not less than eight nor normally more than twenty-four, but provision is made for a greater number if the Minister approves.

Of the members of the board not less than two, nor more than one-fifth, of the total number of members are to be persons appointed by the Minister.

The members appointed by the Minister must hold, in the Minister's opinion, certain qualifications, e.g., they must be "specially conversant with the interests of consumers of the regulated product"; and this means people who buy the product for consumer use and not people who buy it for the purposes of trade or industry.

Powers of the Minister to Direct or Control Marketing Boards—These powers are dealt with by sections 2 to 4 of the new Act. Note, however, the powers which the Minister had, and still has, under section 9 of the 1931 Act. Under that provision the consumers' committee and the committee of investigation were established, each committee being appointed by the Minister. The job of the committee of investigation was to consider any report made by the consumers' committee and any complaints made to the

committee of investigation; and if the committee of investigation reported to the Minister that any provision of a scheme, or any act or omission of a board administering a scheme, was contrary to the interests of consumers of the regulated product, or to the interest of any persons affected by the scheme, and was not in the public interest, the Minister could exercise any of the following powers if he thought fit:—

(*a*) amend the scheme; (*b*) revoke the scheme; (*c*) give directions to the Board to rectify the matter complained of. The Board must forthwith comply with the direction.

An order revoking the scheme had to be approved by Parliament and any other Order under the section had to be laid before Parliament and could be annulled by either House if they passed a resolution to that effect.

The new powers are in addition to those existing under the 1931 Act mentioned above.

Section 2 of the 1949 Act deals with what have been called "permanent directions." Under this section the Minister has power to give directions to a board in relation to the matters set out below where he is of opinion that the acts or omission of the board in question are contrary to the public interest. The acts or omissions so subject to direction are those:—

(*a*) which restrict the purpose for which the product may be used (an example of this might be where surplus liquid milk was used for the manufacture of cream instead of cheese, where the national interest demanded the manufacture of cheese);

(*b*) which limit the quantity of the regulated product which might be sold (an example of this might be the Potato Riddle Regulations or the Hops Quota Scheme);

(*c*) which regulate the price at which the product is sold. This is self-explanatory;

(*d*) which limit the classes of persons through or to whom the product may be sold.

It should be observed here that it must be the act of the Board which is restrictive. The Minister cannot direct the Board to sell only to one class of persons, but he could prevent the Board from deciding to do so.

The section contains a number of safeguards relating to the exercise of these new powers. These are as follows:—

1. The Minister cannot direct the Board to do anything which they have no power to do under their scheme.
2. Before making an Order the Minister must give the Board written notice stating the action which he proposed to take and his reasons therefor, and he must not make an Order for at least twenty-eight days from that notice.
3. If within that period of twenty-eight days or an extended period (which the Minister has power to grant) the Board request reference of the question to the committee of investigation, the Minister must refer the question to the committee accordingly, and cannot make any Order until the report of the committee has been considered by him.
4. On such a reference the committee must consider the matter and subsequently report to the Minister, and the conclusions of the report must be published.
5. In all cases the Minister cannot make any Order at all until he has consulted the Board, and in the case of products not covered by the First Schedule to the Agriculture Act, 1947, i.e., the non-review commodities, he cannot make an Order unless the committee of investigation report in favour of the Minister's view, i.e., that the act or omission of the Board has, or is, likely to have, the result specified in paragraphs (*a*) to (*d*) above-mentioned, and is contrary to the public interest.
6. In any case, any Order made must state the general nature of the reasons for making it and must be laid before Parliament, and is subject to annulment by resolution of either House.

Provision is made for a Board to furnish the Committee of Investigation on such a reference as is above-mentioned with accounts and other information relating to the Board's functions as the committee may reasonably require; and the Board has power to make representations to the committee on the reference in a manner to be prescribed by regulations. Section 2 also contains provision enabling the Minister to revoke or vary any Order so made so as to withdraw all or any of the directions given thereunder, or to vary or add to those directions in any manner which the Minister thinks

necessary in order to secure the purposes for which the directions were given. But he must always consult the board before he revokes or varies any Order and he cannot, except with the Board's consent, vary or add to his directions unless the need for the variation or addition arose from circumstances which actually obtained when the original directions were given.

Section 3 goes on to provide that a committee of investigation may consist of a chairman and either four or five other members (in place of the old provision where there were only four members other than the chairman). The idea behind this is that one member at least shall also be a member of the Monopolies Commission set up under another Act.

In section 4 is met the power of temporary direction or "interim injunction." This section envisages a case in which the Minister has served his notice under section 2, or has directed a committee of investigation to consider a report made by a consumers' committee or a complaint made to the Minister himself. Under the section the Minister can in such circumstances, if he considers it necessary to take immediate action to prevent injury to the public interest, make what may be called a temporary Stop Order. The object of the Order is to prevent the Board from making a change in a course of action in a matter relating to the subject of the notice, report or complaint. The Stop Order is purely negative in character: it prevents a change being made. Such a temporary Order is again subject to limitations and safeguards. In the first place it must be timed to expire not later than four months from the date when it is made; except that where the matter has been referred under section 2 to the committee of investigation, the temporary Order can continue in operation until three months after the conclusions of the investigation have been published under section 2. There are also time limits in the case of a Stop Order made in the case of action by the Minister under section 9 of the 1931 Act above referred to.

The temporary Order can be revoked or varied by the Minister but not so as to extend the duration of the Order beyond the permitted periods. Any temporary Order must state the general nature of the reasons for making it and is again subject to annulment by either House after being laid before Parliament.

Imposition of Penalties—This subject is dealt with by sections 5 to 8, which adopt some of the recommendations contained in the Report of the Falmouth Committee. The main new provisions are as follows:—

1. Every Board must have a disciplinary committee which must comprise not less than four nor more than six members of the Board with an independent chairman, being a lawyer of seven years' standing.
2. No penalty is to be imposed on a registered producer, except after a hearing by the disciplinary committee and by its majority or unanimous decision.
3. Notice of the hearing and written statement of the charge must be served on the registered producer at least fourteen days before the hearing.
4. No penalty can be imposed for any contravention of the scheme which takes place more than six years (or less if the scheme so provides) before the producer is served with the written statement above-mentioned.
5. The disciplinary committee is given power to award costs to a producer if the charge is withdrawn or is not substantiated.
6. The scheme may provide for the committee to have the power and duty to reconsider and, if necessary, vary their decisions.
7. Every hearing by the committee shall be in public unless the committee for special reasons direct that the whole or part of the hearing shall not be so held.
8. The chairman of the committee may direct that any evidence at a hearing by the commitee shall be given on oath.
9. Where there is an equal division of opinion on the disciplinary committee the chairman's opinion is to prevail.
10. In addition to penalties the Board may recover, by action of the disciplinary committee, losses sustained by them due to the action of the accused producer.
11. Provision is made for the enforcement of decisions of the disciplinary committee as if the proceedings before them were an arbitration, the committee being the arbitrator; and the disciplinary committee as arbitrator has the power to state cases under section 9 of the Arbitration Act, 1934.

Powers of Boards—The next group of sections (Nos. 9 and 10) deal with the powers of Boards. Section 9 enables a Board to promote a more efficient production of the regulated product either by manufacturing or acquiring agricultural requisites, or by rendering services to registered producers. This new power covers, apart from the ordinary case of manufacture of farm equipment, artificial fertilisers, etc., activities of Boards such as the grass-drying undertaking of the English Milk Marketing Board, and such services as the operation of milk recording.

Section 10 imposes some restrictions as to the investment of surplus funds of the Board, and adopts a recommendation of the Lucas Report. The section says that these surplus funds should be invested in trustee securities, but it does give powers to the Minister to approve alternative investments. The section also provides that the way in which surplus funds are invested must be stated in the annual report made by the Board to the Minister and to producers.

FARM INSURANCE

INSURANCE, at least against certain risks, is essential for well-equipped and progressive farmers. Without insurance the fruits of a lifetime's work can be lost in a few hours.

The idea of insurance is not new. In earliest days tribes made collections of tools, weapons, etc., to form stores from which to help any members who lost their possessions by, say, fire. To-day, insurance is, as then, simply a means of ensuring that the misfortunes of the few fall lightly on the shoulders of the many; the man who has a fire loses no more than everybody else, i.e., the money each has paid in premiums. In essentials then, insurance is a mutual arrangement made by any convenient number of people.

Kinds of Companies—There are three kinds of insurance companies: (i) tariff, (ii) non-tariff or independent, and (iii) mutual; the largest of those operating to-day include some of each kind.

Tariff offices are members of an association which binds them to charge fixed minimum premiums for certain risks and to include only certain benefits in their policies. Non-tariff offices are not so bound but work independently and tend to charge slightly lower premiums besides being able to widen the scope of their policies as they wish.

Mutual companies are necessarily independent and aim to return surplus profits to their policyholders who, broadly speaking, replace shareholders as owners. Most mutual companies specialise in insurance for certain industries and claim to make their policies especially suitable for members, knowing their needs and problems. In Great Britain farming has its own mutual insurance society which is the largest of its kind in the world.

Apart from insurance companies there is Lloyd's which, briefly, is an association of persons who are grouped into some hundreds of "syndicates," for each of which an underwriter acts in the Lloyd's building. An insurance placed at Lloyd's must be dealt with by an insurance broker. The policy shows which syndicate or syndicates have agreed to take the insurance and what fraction of the syndicate's

proportion of the insurance each member personally bears. Lloyd's underwriters are non-tariff.

First Considerations—Financial stability, reputation for proper claims settlements, the service that a company's staff and agents are willing and able to give and scope of benefits take precedence over cost of insurance.

When satisfied about the financial stability and claims service of the company with whom he intends to insure a farmer should consider the scope of the policies issued and their cost. Such questions as what insurance is essential; what cover the various policies give and how far short it falls of what is necessary; the relation between cover and its cost; and to what extent economies are justified, must be faced.

Effecting an Insurance—All important insurers have offices in most parts of the country with a large number of full-time or part-time agents. A salaried "inspector" works with all the agents in an area and a farmer may deal with him or with an agent. A proposal form must be completed and signed by the farmer (the "proposer"). The form is in two parts—the prospectus, describing the insurance and giving details of cover and cost; the proposal form proper, in which the proposer states what cover he requires and gives details of himself and his previous insurance "history." It is legal to sign a proposal that has been completed by another person but better to do the whole thing one's-self. It is important (*a*) thoroughly to understand the questions and the replies given, (*b*) to answer each question fully and not to put dashes or ticks as replies, (*c*) to give correct answers in all circumstances. The last is vital; an incorrect answer puts one in the wrong from the start.

When the policy arrives it should be read through immediately. At the end of each year a renewal notice is sent requiring payment in advance of the yearly premiums and in acknowledgment of the renewal premium a renewal receipt is issued, the current one being kept always with the policy. Should a policy be lost, a duplicate should be supplied free.

What Insurances to Have—Most farmers need: Fire (for crops, implements, livestock, etc., and for buildings if owner of farm); Employer's Liability; Motor (private car,

lorry, tractor); General Third Party; Householder's; Life. Strongly recommended is Foot-and-Mouth Disease (Consequential Loss) cover.

Other common insurances are: Storm, Tempest and Hail, e.g., for owners of glass houses. Foaling and Stallion for horse breeders, insuring mares and foals against death (including foaling risks) and stallions against death or disablement. Cattle (Accident and Disease) mainly for pedigree breeders. Transit and Show for exhibitors of stock and horses, covering transit to and from, and risks whilst at, shows and sales. Goods in Transit for farmers who do cattle transporting, etc. Personal Accident and Sickness for those whom incapacity would cause financial loss through having to hire extra help, etc. Hail Crops, usually taken only in certain areas.

Finally, there are many special policies, some of which are used only in relatively uncommon circumstances. " All Risks " insurance applies to jewellery, furs, holiday baggage, etc. " T.B. Reactor " cover provides for payment in certain circumstances when an attested herd owner has an animal react at a routine T.B. test. Poultry breeders can have cover against consequential losses through fowl pest. Tenant farmers effect insurance against claims by landlords whose buildings may be damaged by fire caused by negligence of the tenant or his servants. A farmer requiring exceptional cover should apply to an insurance company specialising in agricultural business. Most reasonable risks are insurable.

FIRE INSURANCE

The proposal form contains a number of printed items and, by the side of each, the proposer puts the amount for which he wishes to insure. One item covers growing crops, stacks of hay, corn and straw, manure heaps and all horticultural and market gardening produce; any of such property that is within 60 yards of a railway line is separately insured. Other items cover implements, machinery, harness, utensils, tools, etc.; dead stock such as coal, building materials, fuels, artificial manures, manufactured feeding stuffs; livestock; poultry, including eggs and chicks under heat; household goods. Some items (not those on livestock, implements and household goods) are marked " Subject to the Special Condition of Average." Most farmers do not understand this

clause and, as it is most important that they should, an explanation follows.

Farmers often claim that, as agricultural produce is spread about the farm and cannot all be burned at once, the amount for insurance should be the greatest value at one place. Similarly, a man owning one house worth, say, £1200, in each of 100 towns might contend that, as only one is likely to burn at a time, the whole—worth £120,000—ought to be insured at the cost of the cover for £1200. Each house has its own potentialities for being damaged by fire, exactly as if each were separately owned; and a policy for only £1200 covering all the houses would bear an "average clause" stating that the proportion of any agreed damage that would be paid would be the proportion that the amount of insurance bore to the full value; so a claim could be paid in full only if the sum insured equalled the value. In farming because the amount of produce at risk is low from, say, December to May, the ordinary Average Clause does not apply. Instead, the special clause states if the sum insured equals *three-fourths* of the value any under-insurance will be ignored although the sum insured must be the limit of payment, of course. When, however, the insurance falls below three-fourths of the value the ordinary Average Clause operates in full. The effect can best be judged from this table dealing with three hypothetical fires:—

No.	Sum Insured	Value	Amount of Loss	Amount Paid
1	£750	£1000	£600	£600
2	£750	£1000	£950	£750
3	£750	£1250	£500	£300

In No. 1 the insurance just equals three-fourths of the value and the clause does not operate. In No. 2 the clause similarly does not operate but the sum insured is too small to pay the full loss. In No. 3 the sum insured is not equal to three-fourths of the value and therefore 750/1,250 (or three-fifths) of £500 only can be paid.

The proposal form should show all the important exclusions that will be in the policy. One is that loss of property through its own spontaneous combustion is excluded but it can be arranged with one insurance company for a hot haystack to be tested and, within the terms of the scheme, if the stack cannot be prevented from firing, it will be paid for.

The policy ought to cover, without extra charge, agricultural produce sent away for processing, e.g., corn to be cleaned, dried or ground, grass to be dried or pulverised.

In all good policies, stock is insured whilst at agistment. Lightning is included in fire policies and, for livestock, is much the greater risk.

Eggs in incubators and chicks in hovers are a heavy insurance risk when heating is by oil. If they are not specially mentioned in the proposal form, enquiries must be made, as many companies refuse to insure them.

The sums proposed for insurance must be adequate and it is well to make sure that the policy does not contain a low limit of value for any animal or implement. It is advisable not to have the policy renewable at Michaelmas—most farmers do—a good time being May or June when arable acreages and prices are known, yields can be established and the amount of insurance revised if necessary when the renewal premium is paid. If the policy is renewable on 29th September or 11th October a serious fire early in September may find the sum insured, fixed eleven months earlier, to be disastrously low.

FARM BUILDINGS

The buildings will be described in the policy with a note of the materials of which each is built. One amount is placed on each detached building and each block of buildings that all adjoin. If one finds the policy has one amount on separate buildings (other than a house and its domestic offices) it is most likely the insurance company believes that they do adjoin and they should be informed of the true position.

Under-insurance on buildings is rife. To-day the great majority of farm buildings are not insured for half their values and farmers constantly suffer serious losses through it. Farms commonly change hands for less than it would cost to erect the buildings. If a farm building or a cottage must be replaced care must be taken to insure for the proper amount. Only if a cottage is redundant or a rambling range can be replaced by a compact smaller building should the reinstatement cost be ignored.

In the case of a mortgage the mortgagee will require his

interest to be noted in the insurance and he holds the policy. The insurance company will supply a duplicate copy free.

The following are typical approximate charges:—

TABLE 110—RATES OF INSURANCE

	per cent. s.	d.	
Agricultural produce, implements and dead stock	6	0	i.e., 6s. per £100 sum insured.
Agricultural produce near railway line	8	6	
Livestock	2	6	
Poultry and eggs under heat ...	8	6	to 12s. 6d.
Poultry and eggs not under heat...	2	6	
Household goods	1	9	upwards according to construction of house.
Houses and cottages brick or stone built and slated or tiled ...	1	3	
Houses and cottages thatched ...	5	0	upwards.
Farm buildings not thatched ...	2	6	
Farm buildings thatched	7	6	upwards.

EMPLOYER'S LIABILITY

The State has taken over the liability the employer had under the Workmen's Compensation Acts but there remains the employee's rights against his master at Common Law. (Common Law refers to the right that A has against B if the latter's careless, wilful or negligent action causes A loss or injury, irrespective of any statute.) Under the Workmen's Compensation Acts the employer was responsible for all accidents at work, whether he was at fault or not, but his liability was limited. At Common Law he must be proved to have been negligent, but the amount of his liability is quite unlimited. He may be negligent through doing something or through failing to do something, directly or through one of his servants. For example, he may personally handle a vehicle or tool carelessly; he may order or permit an unsafe method of working; he may supply, or be aware of a defect in, a machine or in his buildings or premises. In addition, since the repeal of the Workmen's Compensation Acts, an employer has been made responsible for the careless, wilful or negligent acts of one employee to another. Farmers should understand that their liability in this is great and growing.

The premium is based on the amount of wages paid in a year. The first premium is paid on an estimate for the

coming year and at each renewal date the insured is asked to give a statement of wages paid in the past 12 months when adjustment is made. Many farmers avoid trouble by asking their insurance agents to refer to their accountants for these figures which is an excellent idea.

A good policy covers, without extra charge, such work as use of explosives to clear ground; horse-breaking for own use; building maintenance or repairs; loan of men to other farmers.

Rates—For all ordinary farm employees the rate is 6s. 6d. to 7s. 0d. per cent. on wages paid and this rate should include any threshing, timber sawing and carting done. Domestic servants are usually rated at about 1s. 3d. per head and clerical and secretarial staff at 6d. per cent. on wages.

MOTOR INSURANCE

Private Cars—A motor vehicle may not be used on a public road unless there is in force, relative to it, a certificate of insurance. The term " motor vehicle " includes a tractor or self-propelled implement and use on the road includes crossing under power from one gate to another. It is generally said that there must be a Third Party insurance in force, although a Third Party policy usually gives more cover than the Road Traffic Acts require.

What is a third party? An insurance policy is a contract between two parties—the insurer (or company) and the Insured. Sometimes it covers the latter's liability to any person to whom he may cause loss or injury and such a person then becomes the third party to the contract. A Third Party motor policy covers such liability; a Comprehensive policy covers also damage to the car and personal accident and medical benefits, etc. Unless a car is too old a Comprehensive policy should always be taken. Some farmers have " Third Party Only " policies because, for damage to their cars, they " can always go for the other man." That does not work when the other man's fault cannot be proved. Similarly, it is inadvisable to take the discount offered for " Owner only driving." A comprehensive policy should contain all these benefits. Many do not.

1. Manslaughter Defence. The ordinary legal defence cover is, in fact, limited to proceedings in a court of

summary jurisdiction—which does not deal with manslaughter cases. As the cost of defence against such a charge is likely to be heavy the policy must clearly mention this cover.

2. "Reckless or dangerous driving causing death." This is a new charge introduced in 1956. The policy must specify that the cost of defence is covered. It should be free.
3. Personal Accidents. This cover usually applies to the insured only. It should apply also to the Insured's wife or husband.
4. Medical Expenses. Loss of rugs and luggage. When these are included the limits should be noted. It is possible to obtain limits of 25 guineas and £25 (twenty-five pounds) respectively.
5. Trailers. Not only should the use of a trailer be permitted, like the carriage of livestock and light goods in the car, but the trailer itself should be insured against damage without extra cost.

Certain extensions of the personal accident benefits are obtainable at extra cost.

Insurance companies are pleased to reduce premiums when the Insured bears the first part of each claim, say, £10 or more. It is worth considering taking an excess, as it is called. The renewal premium is reduced if no claim arises in the previous year. Some companies give 10 per cent. at first renewal, 15 per cent. at the second and so up to 30 per cent. at the fifth renewal. The discount is lost when there is a claim but, if no claim occurs in the following year, the scale begins again at 10 per cent. Some companies have other scales, e.g., 20 per cent., 25 per cent. and 30 per cent., with 20 per cent. as the minimum.

Commercial Vehicles—Lorries, vans, etc., may be insured for third party risks only or comprehensively but in the latter case the only addition to third party insurance is cover for accidental damage to the vehicles. There are two points to note.

First, the motor vehicle policies issued by most reputable companies cover frost damage, which can be serious in radiators and cylinder blocks but the insurance is inoperative

unless reasonable precautions are taken. It is not generally thought reasonable to open one draining cock instead of two: or to open both and to walk away without ensuring that they are not quickly blocked by sediment; or to leave any vehicle—car, lorry or tractor—in an open shed in winter with, perhaps, a sack flung over the radiator.

Second, passenger liability must be covered. Employees often give " lifts " with or without their master's knowledge. The latter is liable for the consequence of any negligence and he must, therefore, be sure that his liability to non-fare-paying passengers is covered even if it costs a few shillings extra.

Tractors—Tractors are on a similar basis to commercial vehicles as regards third party and comprehensive insurance, but the use of trailers with tractors complicates the matter somewhat. Trailers are divided into two classes with optional cover available at stated premiums, and in this respect the prospectus should be well studied.

Occasional hire work is allowed free, but some insurers charge more for contractors' vehicles. Some exclude third party liability for crop-spraying in contractors' policies, and others exclude it in all policies. Passenger liability cover is essential and it should not be necessary to pay an extra premium; but, if necessary, it should be paid. Many insurers offer a cheap policy limiting cover to " own and neighbouring farms." It is most inadvisable to accept it and thus be unable to take the tractor to station, sugar factory, corn drier, etc. Standard policies contain some limitations relating to haulage and felling of trees. As regards frost damage it is very easy, with tractors, not to take " reasonable precautions."

Rates (Private Cars)—Rates vary according to geographical situation—districts A, B and C only being of interest to farmers—whether or not the car was manufactured before 1/1/47 and size of engine. Cars made before 1/1/47 are rated on h.p.; others on c.c. The latter cost more to insure. The premiums in Table 111 are examples of the gross premiums that one might hope to pay (1957).

Commercial Vehicles—Rates vary with situation, class of licence held and vehicle's carrying capacity. Those garaged in and near certain named large towns cost more to insure than those in country districts.

TABLE 111: PRIVATE CAR RATES

H.P. or C.C.	Value £	Place	Manufactured	Rating District	Premiums	
8 h.p.	300	Wilts.	Before 1.1.47	A	Comprehensive	£12 12s.
					Third Party only	£5 13s.
1100 c.c.	500	Cambs.	After 31.12.46	B	Comprehensive	£17 0s.
					Third Party only	£7 2s.
12 h.p.	600	Yorks.	Before 1.1.47	C	Comprehensive	£19 10s.
					Third Party only	£8 3s.
2300 c.c.	1000	Scotland (most of)	After 31.12.46	A	Comprehensive	£23 5s.
					Third Party only	£8 2s.

Examples of rates in country areas (1957):—

TABLE 112: COMMERCIAL VEHICLE RATES

"C" licence—				
10 cwt.	Comprehensive	£14 10s.	Third Party only	£5 8s.
30 cwt.	"	£17 0s.	" " "	£8 2s.
4 tons	"	£21 10s.	" " "	£13 10s.
"B" licence—				
2 tons	"	£31 10s.	" " "	£19 0s.
"A" licence—				
10 tons	"	£105 0s.	" " "	£46 0s.

Tractors—The following rates are for unrestricted agricultural use (1957). About 12s. 6d. per cent. should be added to them, for value of tractor over £500. Rates are independent of h.p. or situation but they vary, as between companies, more than those for cars and lorries—those below are therefore approximations.

TABLE 113: TRACTOR RATES

Tractors	Comprehensive	Third Party only
Used only by farmers, etc., for agricultural purposes only ...	£3 0 0	£1 0 0
Used by agricultural contractors	£3 10 0	£1 5 0
If pedestrian-controlled ...	£1 10 0	12 6

GENERAL THIRD PARTY

Every person who carries on a business or trade is responsible for any loss or damage caused to the public by himself or his servant in the course of his business, wherever it may occur. A farmer or his employee can cause such loss or damage anywhere by negligently doing, or not doing, something. A dairy farmer may fail to mend a cow shed roof so that a tile may fall and injure a caller. A fire, lighted to burn-off stubble, may spread and destroy a neighbour's stacks. A farm hand may leave open a field gate whilst

catching a mare, allowing a child to wander in and be fatally kicked. Some accidents have remarkable causes. For instance, the removal of the load from a lorry delivering meal at a farm caused the springs to lift the metal cab which touched overhead cables, of which the farmer had given no warning, and a youth was electrocuted. How can a farmer protect himself against the cost of such claims?

Most insurance companies offer farmers policies drawn up for ordinary commercial risks but there are one or two that cater specially for farmers. It is possible to obtain a very comprehensive policy covering all third party risks and, in addition, accidental fatal injury to animals and accidental damage to implements all at a reasonable premium. These policies are very popular with farmers. A résumé of a typical specialised policy:—

1. CLAIMS BY THE PUBLIC through
   use of horses or horse-drawn vehicles or implements;
   use of hand-drawn vehicles or pedal cycles;
   livestock being driven or straying;
   any negligence of the Insured or employees;
   defects in any buildings, plant or machinery;
   carriage of non-fare-paying passengers in horse-drawn vehicles;
   poison, pollution, foreign substances in food or drink supplied;
   fire negligently caused

   Plus any legal costs.

2. EMPLOYER'S LIABILITY INSURANCE plus legal costs.

3. LEGAL LIABILITY TO REPLACE NATIONAL HEALTH INSURANCE STAMPS if lost through any cause.

4. FATAL INJURY TO LIVESTOCK by accident, including conveyance by motor vehicle.

5. ACCIDENTAL DAMAGE TO VEHICLES, HARNESS AND IMPLEMENTS.

6. PERSONAL LIABILITY to the public through sports, pastimes and any private activities.

7. SHEEP WORRYING BY DOGS.

Many companies limit their third party cover, as to the amounts to be paid for any one claim and in any one year. Unlimited third party cover is essential. Suppose a horse, negligently handled, caused a motor coach to overturn, thus killing and injuring most of the occupants; how far would a farmer be protected by an indemnity limit of, say, £5000?

When it is not possible to obtain all the above cover, every effort should be made to secure at least the whole of the third party cover in respect of claims by the public.

Rates—Third party risks are rated on wages, acreage, or a combination of both. Indications of what must be paid to cover third party liability on farms of various sizes are:—

	£	s.	d.
25 acres and £750 wages	1	10	0
100 acres and £1500 wages	1	15	0
300 acres and £3000 wages	3	10	0
1500 acres and £10,000 wages	6	10	0

Cover for livestock is usually charged at a quite nominal rate on the value of stock on the farm or maximum value on the road at a time. For accidental damage to vehicles it is usually based on wages or number of drivers. Sheep worrying premiums are based on values of stock.

HOUSEHOLDERS' INSURANCE

Householders' Comprehensive policies (sometimes given names like "All-in-Policy") are most convenient and extremely good value. Where the construction of the house allows comprehensive cover to be given, this cover is certainly recommended.

These policies cover the chief risks that concern a householder, including especially fire, burglary and storm and tempest, the normal premium for which alone would almost equal that of a Householders' Comprehensive policy.

The many other benefits, including breakage of mirrors, accidents to servants and bursting of water pipes cannot all

be described here but farmers should study several prospectuses before making a choice since one or two weaknesses in many policies are avoided by a few companies who cater for agriculture. Thus, it is common to require the policyholder to bear the first £5 of claims through certain causes and, if possible, this should be refused. It is important that the policy specifically covers the policyholder's liability as a private person, whilst playing games and sports, whilst cycling, etc.

Rates—Premiums are calculated on the sum insured which should be the full value of the contents (an average clause should be refused) and rates are 5s. per cent. upwards according to how the construction of the house affects the fire risk.

Buildings—Houses and domestic offices are commonly insured for fire only but, for a very little more, other important risks such as storm and tempest, bursting of pipes and overflowing of tanks, aircraft, impact by road vehicles and loss of rent may be added. Comprehensive cover is recommended.

When studying prospectuses the requirement to bear the first £5 should occur as rarely as possible.

Rates—A number of alternative schemes are offered and a prospectus should show clearly what risks each scheme covers. Premiums are based on the value of the house and they range, for the widest cover, from 2s. per cent. upwards.

FOOT AND MOUTH DISEASE

Existence of foot-and-mouth disease on any farm usually means immediate slaughter of all cattle, sheep and pigs and the closing of the farm for about six to eight weeks. The Government pays the stock-owner the market value of the destroyed animals. That does not recompense the farmer for heavy financial losses through having to pay wages to employees who cannot be dismissed, loss of profit on milk, wool and other produce, loss of markets and milk rounds, cost of rebuilding herd or flock, continuation of overheads such as rent, personal expenses and so on.

A policy to cover this risk should not be expensive and it is a sound investment. The insurance is usually for a given percentage, say, 25 per cent. of the amount paid by the Government as slaughter compensation; it should be possible

to insure different kinds of stock for different percentages. It should not be necessary to state the numbers of animals. The policy should not contain a waiting period—cover should begin immediately.

Rates—The lowest rates, to pay 25 per cent. of Government compensation, are about 1s. 3d. per cent. (on value of stock) for sheep and 2s. 6d. per cent. for cattle. Pigs, especially on pig farms, may cost a little more.

LIFE ASSURANCE

For any man in average good health there is no better investment than a life assurance.

The income tax rebate on premiums, the fact that payment of the sum assured and its bonus additions is untaxed and the investment facilities of life assurance companies combine to give the policy holder an excellent financial return when the policy matures, with very much greater profit to his estate should he die earlier.

In life assurance the policyholder pays a level premium at regular intervals and on the happening of a certain " event " the company pays the agreed sum, plus bonus additions, or " profits " which vary with the trading results of the company. (Non-profit policies are cheaper but are not recommended.) In whole-life policies the " event " is the Life Assured's death; and premiums are paid throughout life or for an agreed period. In endowment assurance the " event " is expiry of a given number of years or death, whichever occurs earlier and premiums are paid until then.

After payment of two or three years' premiums most policies acquire a " surrender value " when a policy may be discontinued and the surrender value (a relatively small proportion of the premiums paid) may be taken. To surrender a policy should be the last resort and the alternative, a " paid-up policy " should be taken. In this, although no further premiums are paid, the policy continues until the " event " and the sum then paid is the proportion of the original sum assured that the number of premiums paid bears to the total number originally payable. For example, a £3000 endowment policy issued for 15 years could be converted, at the end of five years, to a policy for £1000, no more premiums to be payable. Some profits would be added.

Most policies can be issued under the provisions of the Married Women's Property Act, 1882. This step can have two advantages: (1) on the death of the life assured his widow may be paid within a few days and without waiting for grant of probate which often takes weeks and may take years; (2) the policy may be safeguarded for the policy-holder's benefit against his creditors if he should have financial reverses. A farmer should require the insurance official to explain this fully, including such disadvantages as there may be.

One should not effect a life policy without having expert advice from an official of a reputable company. In no other kind of insurance are the pitfalls less obvious and as, broadly, the terms of a life assurance cannot be altered after issue, one must be sure to effect exactly the kind of assurance that one needs.

The following are a few of the many types of policy that are available:—

Family Policy (marketed under several similar names)—Typical benefits: on death within 20 years of effecting policy, £312 a year *tax free*, for the balance of the 20 years and then £2000 in cash; on death after the first 20 years, £2000 in cash. To each of these sums profits would be added—anything from £400 to £1000. Cost: for a man rising 40 about £78 a year.

Pension Policy—The Finance Act, 1956, made far-reaching changes in the law relating to pensions and annuities, involving tax concessions of great advantage to farmers. Briefly, the premiums for pension policies are deducted from earned income before tax is calculated, and the insurance company is exempted from tax on funds ear-marked for this purpose and can thus quote attractive rates. If a premium of £100 be paid, a self-employed farmer paying tax at 8s. 6d. in the £ saves £33 in tax. In the higher brackets a farmer with an earned income of £5000 taking a pension policy at a premium of £500 p.a. actually saves tax of about £300 p.a.

Example of benefits for monthly premium of £16 15s. 0d. (reduced by tax saving to £11 3s. 0d.) paid by man of 35: an annual pension can be taken of £460 beginning at age 60; £664 at 65; or £936 at 70. Pension is paid for 10 years or for life, whichever is longer.

This tax concession is intended to be a great financial help to the self-employed. A successful farmer should take advantage of it to the utmost he is allowed—broadly, premiums may not be more than 10 per cent. of earnings.

Child's Protection Policy—Premiums begin preferably in infancy. When the child is 21 it is offered, *irrespective of state of health*, the choice of a cash sum or of policies maturing at varying ages with or without continuation of premiums; alternatively, a cash sum may be taken earlier for education. The policy should provide that the options be available when the child is 21, irrespective of survival of a named parent until then, and that no more premiums be paid after the latter's death, whenever occurring. This improves the protection and makes the premium rank for income tax rebate. Premiums are usually quoted at round figures—say, £10 a year—and the benefits adjusted accordingly.

Education Policies—These are usually endowment assurances on the life of one parent, providing, at the end of the agreed term or previous death, the sum assured in cash or a slightly larger sum if spread over, say, five years. An outstandingly good plan assumes that a child costs £150 to maintain and educate up to age 13, when public school expenses raise the cost to £450; if the parent dies before the child is 18 those sums are paid annually until the child reaches that age. If the parent survives until the child reaches age 13, premiums cease but can go to the child's upkeep and the policy pays the balance up to £450. A farmer of 35 starting this plan when his child is born, pays £86 yearly, less income tax relief.

Income Tax Rebate—Broadly, the premium paid for assurance on the taxpayer's life or on that of his wife ranks for income tax relief. Only the first £7 per cent. of the premium is counted, which means roughly that if the term of the assurance is less than 15 years not all the premium ranks for relief. Other limitations and regulations may vary from time to time and should be explained fully by an official of the company to whom one proposes; the general effect is that income tax is reduced by about one-sixth of the amount of premium paid. The special tax relief for pensions policies has been mentioned.

Medical Examination—Most companies are willing to dispense with medical examination in any normal case where a reference to the proposer's doctor and to two friends proves satisfactory; there are usually these limits: amount of assurance £2000, age of proposer 50. The company pays for what medical evidence is required in normal cases.

Premium Payments—Many companies are willing to take monthly payments of one-twelfth of the annual premium; payment must be by banker's order and receipts are not given. Monthly premiums are admirable. They enable a farmer, especially the young farmer, to take out life assurance at the proper times—as early and as often as possible.

CLAIMS

The best time to begin dealing with every claim is when the insurance is effected. The following are points to keep in mind *before any claim occurs.*

It does not pay to economise on premiums. To insure reasonably generously helps to take care of any increase in value, or risk, that may go overlooked. One should never sign a proposal form un-read no matter how much one trusts the agent. The policy should be carefully read on receipt, returned for alteration if necessary and then kept in a safe place.

Renewal premiums should be paid promptly; to have all the policies renewable on the same day is an advantage and insurance companies will gladly co-operate.

Insurance is impossible without good faith on both sides and one must be able to trust the company in every reasonable way. Otherwise, a move is indicated; but it is not advisable to let the company hold similar ideas about the Insured.

When any possible cause for a claim arises—even if not an immediate claim—the policy should be read carefully and the instructions followed. If an animal is thought to be struck by lighting, for instance, the company must be informed by telephone or telegram and allowed to see the carcase. If one is involved in a motor accident one must be quite sure to take the name and address of any witness and not to make the slightest admission of any liability.

Assessors are usually independent firms employed by many insurance companies and holding no brief for any particular

company for which they act. If they inform the insurers that one is entitled to less than is claimed, there will be a reason. If one deals reasonably with the insurers they will deal reasonably in turn. It practically never pays to tell them " Pay my claim in full or I take my insurances away "—they will probably let one go. On the average, an insurance company's profit is two or three per cent. of its turnover so by paying £100 extra on a claim they are forfeiting the profit on premiums of perhaps £4000—rather more than the ordinary farmer pays in a life-time.

FUTURE TRENDS

These are some of the changes that may be expected to come in the next few years.

Insurance rates will probably increase, even if only because of general inflation. Except for motor and employer's liability insurances they are virtually the same as in 1939. So far as agriculture is concerned rates for fire insurance may rise unless more care is exercised on the farm because statistics show clearly that most farm fires occur through carelessness, the most culpable being the lighting, without taking adequate precautions, of fires to destroy threshing rubbish, clamp bottoms, hedge trimmings, straw left by combines, etc. Rates may be increased for produce growing near railway lines and they are steadily rising now for thatched buildings, especially when in the majority on a farm. Farms near large towns are bad fire risks; farmers know this and will not be surprised at any premium increase.

Claims by workmen under Employer's Liability insurance have proved to be numerous and the awards in contested cases are high and still increasing. Increases in premium rates have been made in recent years but it is thought that there may be more.

Awards to third parties in motor accidents have steeply increased during recent years and this, together with the ever-rising cost of motor repairs, has brought several increases in rates, the most severe, so far, being in 1957. There is little doubt that these trends will continue and that, therefore, rates must rise. Exceptionally worsening experience in and near populous areas, suggests, however, that the cost to farmers of insurance should not rise as steeply as for the townsman.

Where rates are based on values, e.g., fire insurance, inflation tends to raise premiums automatically. In other cases, e.g., public liability insurances, this is not so and from time to time rates must be increased arbitrarily.

A tendency that will be welcomed by most farmers is that of putting more risks into one policy so as to reduce the number of documents necessary for complete cover. Several companies are beginning to do this, especially those specialising in farm insurance. It is probable that other companies will begin to explore the agricultural market—there are already signs that some are interested. On the whole they will offer the farmer good security and normal premiums. The service that they can give to their policyholders in scattered country districts and the scope of the cover in their farmers' policies is, perhaps, not so certain.

Farming practice, especially as it may affect insurance, is changing continually. For instance, the increase in mechanisation is at present tending to produce more fires and more accidents and the rapid growth of the practice of crop spraying is causing problems of magnitude, especially in connection with spraying done by farmers who, on the whole, tend to take less care than established and reputable contractors and are thus doing heavy damage to neighbours' crops all too often. These and other problems may put inexperienced companies in some difficulties but a small number of insurance organisations with wide and established agricultural connections will be able to adjust their practice in the light of modern developments. However, it is certain that until much more care is taken, in spraying crops, to avoid wind-drift and blow-off, and until farmers stop the senseless wrecking of tractor radiators and cylinder blocks through widespread and careless lack of protection against frost, their tractor premiums must inevitably keep rising.

The Agriculture (Safety, Health and Welfare) Act, 1956, will have a powerful influence on farming practice. It is an enabling Act under which the Minister of Agriculture issues regulations controlling, amongst other things, the employment of children, the management of animals, systems of work, the guarding and use of machinery and the construction and use of buildings. The Minister's first regulations, that is, relating to the provision of first-aid boxes and the guarding of p.t.o's and shafts on tractors and imple-

ments, for example, indicate the thoroughness with which the whole vast subject will be treated. Many farmers will be astonished at the range and exhaustiveness of the regulations that will flow from the Minister in the next few years. Some will feel aggrieved at the inconvenience and the expense to which they will be put. Undoubtedly farmers' liability to their workmen will be heavier because of the duties imposed on them by statute and to have comprehensive third party insurance covering workmen on the farm, *whether at work or not*, is of paramount importance. If the Act achieves its object and substantially reduces the number of accidents on farms it should be reflected in a lowering of premiums.

MENSURATION

MENSURATION is that branch of mathematics which deals with the determination of the lengths of lines, areas or surfaces, and volumes of solids.

The following tables are those commonly used in mensuration:—

LINEAR, WEIGHT AND CAPACITY

Linear Measure

12 inches = 1 foot
3 feet = 1 yard
$5\frac{1}{2}$ yards = 1 rod, pole or perch
220 yards or 40 poles = 1 furlong
1760 yards or 8 furlongs = 1 mile

Square Measure

144 square inches = 1 square foot
9 square feet = 1 square yard
$30\frac{1}{4}$ square yards = 1 square pole or perch
40 square poles = 1 rood
4840 square yards or 4 roods = 1 acre
640 acres = 1 square mile

Cubic Measure

1728 cubic inches = 1 cubic foot
27 cubic feet = 1 cubic yard

Liquid Measure

4 gills = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon

Dry Measure

2 gallons = 1 peck
4 pecks = 1 bushel
8 bushels = 1 quarter

Area of Planes

$$\text{Area of square} = (\text{length of side})^2$$

$$\text{Area of rectangle} = \text{length} \times \text{breadth}$$

$$\text{Area of triangle} = \frac{\text{base} \times \text{perpendicular height}}{2}$$

$$\text{Area of circle} = \pi \times (\text{radius})^2$$

$$= \frac{\pi}{4} \times (\text{diameter})^2$$

$$= \frac{(\text{circumference})^2}{4\pi}$$

The value adopted for the constant π is generally $\frac{22}{7}$ or 3·1416.

For most practical purposes the area of a circle may be calculated from the formulae:—$0{\cdot}8d^2$ or $0{\cdot}08C^2$ where d and C are the diameter and cicumference respectively.

Volumes

Volume of rectangular solid = length $\times$ breadth $\times$ height.

Volume of cylinder—area of end $\times$ height $= \frac{\pi d^2}{4} \times h$.

Useful Figures

1 gallon of water weighs 10 lb.

1 cubic foot of water weighs $62\frac{1}{2}$ lb. nearly.

1 cubic foot of water = $6\frac{1}{4}$ gallons nearly.

1 cubic foot of hay (in stack) weighs 6–10 lb.

1 cubic foot of silage weighs 40–48 lb.

1 cubic foot of potatoes in clamp weighs about 42 lb.

1 cubic foot of farmyard manure weighs 50–66 lb.

Weights and Measures

Hay Bales—Rectangular bales from the ram type baler vary from $5\frac{1}{2}$ to 7 cubic feet capacity. The weight of the bale varies according to the moisture content:—

Moisture Content %	Bale Density lb. per cu. ft.	Weight per bale of 6 cu. ft. (lb.)
20	14	84
25	12	72
30	10	60

Grain, etc.

Grain	Wt. per bushel (approx.) lb.	Wt. per quarter (approx.) cwt.	Cu. ft. per ton (approx.)	Ground Meal Cu. ft. per ton (approx.)
Wheat	63	$4\frac{1}{2}$	46	70
Barley	56	4	51	69
Oats	42	3	70	120
Rye	57	4	51	69
Peas	63	$4\frac{1}{2}$	46	65
Beans	66	$4\frac{3}{4}$	43	58
Linseed	54	4	51	69

1 bushel = 1·285 cu. ft.

Calculation of Cubic Contents of Stacks and Silos

1. Rectangular Stack

(*a*) volume of lower part = average length × average breadth × height to eaves.

(*b*) volume of upper part =

$$\frac{\text{length} \times \text{breadth (at eaves)} \times \text{height (eaves to ridge)}}{2}$$

Total cubic content = a + b.

2. Circular Stack
   (*a*) volume of lower part$=0{\cdot}08\times$(average circumference)^2 $\times$ height to eaves.
   (*b*) volume of upper part$=\frac{1}{3}\times0{\cdot}08\times$(circumference at eaves)$^2\times$height.
   Total cubic content$=$a$+$b.
3. Pit or Clamp Silo
   Cubic content = length $\times$ average width $\times$ depth.
4. Circular Tower Silo
   Cubic content = $0{\cdot}8\times$ (diameter)$^2\times$ height.
   or $0{\cdot}08\times$ (circumference)$^2\times$ height.

SURVEYING

Surveying may be considered as that branch of applied mathematics which deals with the measurement of land.

Ranging out Lines

(*a*) To range a line between two points A and B on fairly level land, sight from A, insert ranging poles at C, D and E, working from B towards A. The bottom of the ranging poles should be observed.

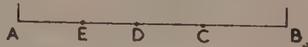

FIG. 40

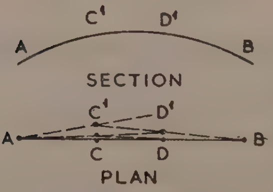

FIG. 41

(*b*) To range a line between two points A and B with

undulating land between so that B cannot be seen from A. (See Fig. 41.)
Two assistants take up positions C′ and D′, so that C′ can see B and D′ can see A. They then direct each other in turn into line with A and B until points C and D are reached, when no further shift is possible. ACDB is then a straight line.

(*c*) To range out a line between two points A and B with a steep slope intervening:

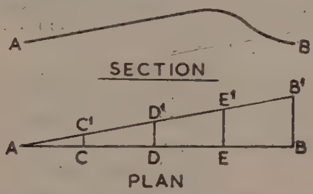

Fig. 42

Range out a trial line AB′ in the general direction of B, marking stations C′, D′, E′. Measure AB′, noting the distances from A to C′, D′ and E′. B′B, the ranging error, is also measured.
Consider E′E, D′D and C′C drawn parallel to B′B.
Triangles AB′B and AE′E are similar—hence:

$$\frac{E'E}{AE'} = \frac{B'B}{AB'}$$

$$\therefore \quad E'E = \frac{B'B \times AE'}{AB'}$$

D′D and C′C can be calculated in the same way. E′E, D′D and C′C are then moved parallel to B′B to give straight line ACDEB.

d) To continue a chain line obstructed by a building: Range out the chain line to the building. Choose two points A and B on this line, erect perpendiculars AC and BD of equal length to clear the building. From C, range a line through D, past the building and

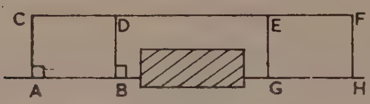

FIG. 43

choose two points E and F. Drop perpendiculars EG and FH equal in length to AC and DB. (See Fig. 43.) From G, continue the chain line through H. To give greater accuracy AB and GH should be three times the length of the perpendiculars.

For small areas a simple chain survey may be made, using the Gunter's chain. The Gunter's chain is 22 yards in length and consists of 100 links. There are 10 chains to the furlong and 80 chains to the mile.

10 square chains or 100,000 square links = 1 acre.

The area to be surveyed is divided into any convenient number of triangles:

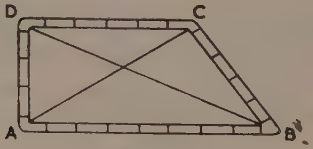

FIG. 44

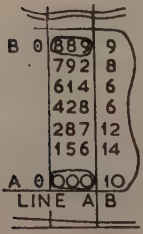

FIG. 45

Stations ABCD (Fig. 44) are chosen in the corners of the fields. Lines DB, AB, BC, CD and DA are ranged out, dividing the greater portion of the area into two triangles. Line AC may also be ranged out and measured as a check line. When measuring AB, BC, CA and DG offset measurements are taken to the boundary, wherever it changes direction, as indicated by the broken lines.

Taking line AB as an example, measurements in links could be entered in the field book as shown in Fig. 45. From the field notes the area may be drawn to a convenient scale, and the area calculated from the plan:—

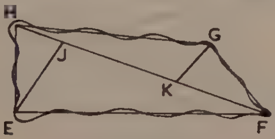

FIG. 46

Curved boundaries are replaced by equalising lines, so that figure EFGH is equal in area for all practical purposes to the original field.

Draw in diagonal HF and erect perpendiculars EJ and KG. Scale off these lines.

$$\text{Area} = \text{HF} \times \left(\frac{\text{EJ} + \text{KG}}{2}\right)$$

ORDNANCE SURVEY

The maps of most importance to agriculturists are the 6-in. and 25-in. maps.

Map 6 in. to the mile (1/10560)—This map is useful to the estate owner. The whole map covers an area 6 miles by 4 miles, and is published in quarter sheets, each covering an area 3 miles by 2 miles. All boundaries, county, parliamentary, urban, rural and parish are shown, as also are all enclosures, buildings, etc. In the vicinity of towns, streets are widened to accommodate street names. Instrumentally determined contour lines are drawn in at 50 ft., 100 ft., then at 100-ft. intervals to 1000 ft. and thereafter at 250-ft.

intervals. Bench marks are given to one place of decimals of a foot, while numerous spot levels are shown.

Map 25·344 in. to the mile (1/2500)—Termed the parish or farmer's map, each sheet covers 960 acres or 1½ square miles. All features shown on the 6-in. map are shown except contour lines. All enclosures bear a reference number and the acreage to the third place of decimals. One square inch on this map is practically equal to one acre.

Index to 6-in. and 25-in. maps—Index maps are published for each county, to the scale 4 in. to the mile. On this, numbered rectangles show the area covered by each 6-in. sheet. These are recognised by Roman numerals. The 6-in. quarter sheets are recognised by the compass points. The 6-in. sheet lines are further divided into 16 small rectangles, each representing an area covered by one 25-in. sheet. These are recognised by Arabic numerals ranging from 1 to 16.

The following diagram of one 6-in. rectangle illustrates the above:

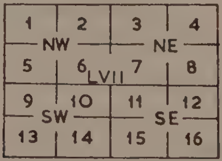

FIG. 47

To order the 6-in. sheet state:—

County,
Six-inch sheet number,
Scale.

Example:—Devon LVII 6 inches to the mile.

For 6-inch quarter sheet, N.E.

Example:—Devon LVII N.E. 6 inches to the mile.

For 25-inch sheet 10.

Example:—Devon LVII 10, 25·344 inches to the mile.

APPLIED MECHANICS

Force—That which changes or tends to change the state of rest or motion of a body. The unit of force is the lb. weight.

Moment of a force—Is the turning effect of a force and is equal to the product of the magnitude of the force and the perpendicular distance from the point about which the force is acting, on to the line of action of the force.

Example:—If force F is acting about a point P at perpendicular distance S, then the moment of F about P = FS.

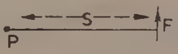

FIG. 48

Levers—A lever is a simple rod or bar capable of turning about a fixed point termed the fulcrum. Three types of lever are generally recognised:—

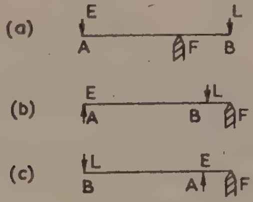

FIG. 49

In each case E represents the effort, acting at distance AF from the fulcrum, and L the load acting at distance BF from the fulcrum. Taking moments about the fulcrum, then in each case, for equilibrium:—

$$E \times AF = L \times BF$$

In (*a*) and (*b*) a relatively small effort will be required to move a relatively large load and we have what is termed a mechanical advantage. In (*c*) a large effort will be required

to move a relatively small load and we have what may be termed a mechanical disadvantage.

Practical Applications—(*a*) The lever of a safety valve on a steam boiler is provided with a 6-lb. adjustable weight. The weight of the lever is 3 lb. and its centre of gravity is 8 in. from the fulcrum. The centre of the valve is 3 in. from the fulcrum, its weight is 1 lb. and its diameter 1 in.

To calculate the distance the 6-lb. weight should be placed from the fulcrum, so that steam will blow off at a pressure of 56 lb. per sq. in.

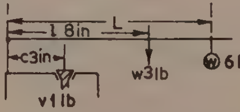

FIG. 50

Taking moments about fulcrum F when boiler is on point of blowing off steam.

$$W \times L + w \times l = (Pa - V) \times C$$

Where W = weight on end of lever in lb.

L = distance weight has to be placed from fulcrum

w = weight of lever

l = centre of gravity of lever from fulcrum

P = pressure in lb. per sq. in.

a = area of valve

C = distance from fulcrum to centre of valve

V = weight of valve

$$(6 \times L) + (3 \times 8) = \left(\left(56 \times \frac{11}{14} \times 1 \times 1\right) - 1\right) \times 3$$

$$6L + 24 = 129$$

$$6L = 129 - 24 = 105$$

$$L = \frac{105}{6} = 17\tfrac{1}{2} \text{ in.}$$

(*b*) In the hydraulic lift of a tractor the piston is supplied with oil at a pressure of 2000 lb. per sq. in. The piston is $2\frac{1}{2}$ in. in diameter, and the connection to the lift shaft is 6 in. The lift arm is 1 ft. in length, and the lift link is connected to the draught-link at 1 ft. from the fulcrum of the draught link. The draught link is 3 ft. in length. Calculate the weight that can be lifted at the end of the draught link.

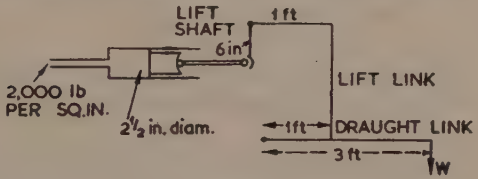

FIG. 51

$$\text{Total pressure on piston} = \frac{11}{14} \times \frac{5}{2} \times \frac{5}{2} \times 2000 = 9821 \text{ lb.}$$

Let F = force on end of lift arm. Taking moments about lift shaft.

$$9821 \times \tfrac{1}{2} = F \times 1. \qquad F = 4910 \text{ lb.}$$

Taking moments about fulcrum of draught link.

$$4910 \times 1 = W \times 3. \qquad W = \frac{4910}{3} = 1637 \text{ lb.}$$

Work—When a force acts on a body and causes it to move then work is said to be done. The unit of work is the ft.-lb., which is the work done when a weight of 1 lb. is lifted vertically through 1 ft.

Power—This is the rate of doing work. The unit of power is the horse-power and is a rate of working of 33,000 ft.-lb. per minute or 550 ft.-lb. per second.

Indicated Horse-power (I.H.P.) is the horse-power developed inside the cylinder or cylinders of an engine. It may be looked on as the theoretical horse-power of the engine.

$$\text{I.H.P.} = \frac{\text{PALN}}{33{,}000}$$

where P = mean effective pressure in the cylinder in lb. per sq. in.

A = area of the piston in sq. in.

PA = total effective pressure in the cylinder in lb.

L = length of stroke of piston in ft.

PAL = work done per stroke in ft.-lb.

N = number of power or working strokes per minute

PALN = work done per minute in ft.-lb.

Brake Horse-power (B.H.P.) is the horse-power given out at the rim of the flywheel of an engine as measured by a brake. In the agricultural tractor it is the power which is available for driving machinery by belt, power take-off shaft or for moving the tractor and pulling the implement.

$$\text{B.H.P.} = \frac{(\text{W} - \text{S})\ \text{CN}}{33{,}000}$$

where W = dead load on the brake in lb.

S = spring balance reading in lb.

(W − S) = effective load on brake

C = circumference of brake-wheel in ft.

(W − S)C = work done per revolution in ft.-lb.

N = number of revolutions per minute

(W − S)CN = work done per minute in ft.-lb.

Mechanical Efficiency—The mechanical efficiency of an engine is the ratio of the Brake Horse-power to the Indicated Horse-power, generally stated as a percentage.

$$\text{M.E.} = \frac{\text{B.H.P.}}{\text{I.H.P.}} \times 100 \text{ per cent.}$$

Drawbar Horse-power (d.b.h.p.) is the horse-power at the drawbar of the tractor or the power available for pulling

implements and machines. It is numerically equal to the Brake Horse-power less the power used in overcoming friction in the transmission and moving the tractor over the soil surface (i.e., overcoming rolling resistance).

$$\text{d.b.h.p.} = \frac{\text{drawbar pull in lb.} \times \text{speed in feet per minute}}{33{,}000}$$

$$\text{or } \frac{\text{drawbar pull in lb.} \times \text{speed in miles per hour}}{375}$$

The ploughing resistance of a soil is generally stated in pounds per square inch of furrow slice cross section. For soil in reasonable ploughing condition the resistance may be taken as:—

Sand to sandy loam ...	5– 8 lb. per sq. in.
Loam	9–11 lb. per sq. in.
Clay loam	12–14 lb. per sq. in.
Clay	14–16 lb. per sq. in.

Example—A tractor pulls a three-furrow plough cutting furrows 10 in. wide and 6 in. deep at a speed of 3 m.p.h. on soil estimated to have a resistance of 10 lb. per sq. in. of furrow slice cross section. Calculate the drawbar horse-power expended.

Cross-sectional area of furrows $= 10 \times 6 \times 3 = 180$ sq. in.

Total resistance or drawbar pull required $= 180 \times 10 = 1800$ lb.

$$\text{d.b.h.p.} = \frac{\text{drawbar pull in lb.} \times \text{speed in m.p.h.}}{375}$$

$$= \frac{1800 \times 3}{375} = 14{\cdot}4$$

Tractor Wheel Slip—When a tractor is pulling a load there is generally some slip between the drive wheel and the soil surface, resulting in reduced speed over the ground.

Slip may be estimated by marking and measuring the distance covered in, say, 10 revolutions of the drive wheel when pulling a load and over similar ground with no load. If A is the distance travelled with no load and B the

distance travelled under load, then wheel slip percentage will be:—

$$\frac{A - B}{A} \times 100.$$

With pneumatic tyred tractors wheel slip greater than about 15 per cent. will result in too much loss of power.

Adhesion may be improved by adding weight to the rear wheels of the tractor, either by wheel weights or by ballasting with water.

Thermal Efficiency of an Engine is the capacity of the engine to convert the heat energy contained in the fuel to useful mechanical work.

The British Thermal Unit (B.Th.U.) is the amount of heat required to raise the temperature of pure water one degree Fahrenheit.

The heat energy contained in engine fuels is stated in British Thermal Units per pound:—

Petrol about	20,000	B.Th.U. per lb.
Tractor vaporising oil about ...	19,900	„ „
Tractor diesel fuel about ...	19,600	„ „

One British Thermal Unit is equivalent to about 778 ft.-lb. of mechanical work. The thermal efficiency of engines is:—

Petrol and vaporising oil ...	25–30	per cent.
Diesel	35–40	„

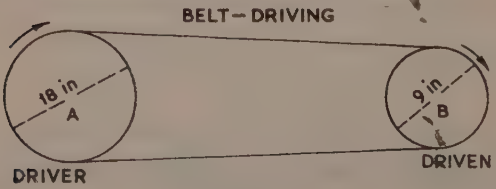

Fig. 52

A common method of driving a machine from a parallel shaft is by means of a flat belt running over pulleys.

If the driver A has a diameter of 18 in. and the driven

pulley B a diameter of 9 in. and if there is no slipping, then during one revolution of A its circumference and the belt will move 18π in. Similarly, if there is no slipping at the driven end, pulley B will also move 18π in. But one revolution of B is 9π in., therefore the revolutions made by B while A makes one revolution will be:—

$$\frac{18\pi}{9\pi} = \frac{18}{9} = 2$$

$$\text{or velocity ratio B to A} = \frac{\text{speed of pulley B}}{\text{speed of pulley A}} = 2$$

Let D be diameter of A, d be diameter of B, N be the revolutions per minute of A, n be the revolutions per minute of B.

Then for each revolution of A, the revolutions of B $= \frac{D}{d}$

If A makes N revolutions per minute B will make $\frac{D}{d}$ times as many, or we can say:—

$$n = \frac{N \times D}{d}$$

i.e., revolutions per minute of B =

$$\frac{\text{revolutions per minute of A} \times \text{diameter of A}}{\text{diameter of B}}$$

Slipping of Belts—When a belt is transmitting power there is generally some slipping forward of the driver without carrying the belt with it, and some slipping forward of the belt over the follower may also take place. There is also a small, but continuous, creeping of the belt over the pulleys, due to unequal stretching. For these reasons a belt and pulley do not give a " positive " drive, such as is obtained by chains. A belt drive should, therefore, not be used where an exact velocity ratio is required.

Horse-power Transmitted by Belts—The follower is

pulled round by the frictional grip of the belt because the pull of the belt is greater on the one side than on the other.

Let T1 be the tension in the tight side of the belt in pounds, T2 be the tension in the slack side of the belt in pounds, then the effective turning force at the circumference of the follower = T1 − T2 lb.

FIG. 53

If V = the velocity of the belt in feet per minute, then the work done per minute = (T1 − T2) V ft.-lb. Therefore

$$\text{horse-power transmitted} = \frac{(T1 - T2)V}{33{,}000}$$

V the velocity of the belt in feet per minute = πDN where D is the diameter of the driver in feet and N the revolutions per minute of the driver.

The ratio T1 : T2 is generally 2 : 1 or 5 : 2.

The maximum tension in a belt is generally stated in pounds per inch width of belt. On the average it may be taken as 60–80.

To Calculate the Width of Belt—A hammer mill requiring 20 horse-power to drive it is driven from the belt pulley of a tractor. The pulley is 1 ft. in diameter and makes 900 revolutions per minute. Assuming a belt tension ratio of 2 : 1, and the maximum tension in the belt is not to exceed 80 lb. per inch of width, calculate the width of belt required.

$$\text{h.p.} = \frac{(T1 - T2)V}{33{,}000} = \frac{(T1 - T2)\pi DN}{33{,}000}$$

Therefore
$$20 = \frac{(T1 - T2)\, 22 \times 1 \times 900}{7 \times 33{,}000}$$

$$\text{Therefore } (T1 - T2) = \frac{20 \times 7 \times 33{,}000}{22 \times 1 \times 900} = \frac{700}{3} = 233 \text{ lb.}$$

The tension in the tight side T1 is to be twice the tension in the slack side, i.e., T1 = 2T2.

Substituting 2T2 for T1
we have 2T2 − T2 = 233 lb.
Therefore T2 = 233 lb.
Therefore T1 = 466 lb.

The maximum tension is not to exceed 80 lb. per inch width of belt, so that width of belt $= \frac{466}{80} \doteqdot 6$ in.

Electrical Power—The " Volt " is the unit of electrical pressure. The " Ampere " (amp) is the unit of electrical current. The " Watt " is the unit of electrical power and is the product of volts and amperes, i.e., watts = volts × amps.

746 watts = 1 horse-power.

$$\text{Therefore horse-power} = \frac{\text{watts}}{746} = \frac{\text{volts} \times \text{amps}}{746}$$

In estimating large power the watt is an inconveniently small unit, and the unit used is the " kilowatt " (kW), which is equal to 1000 watts.

One kilowatt = $1\frac{1}{3}$ horse-power. The " unit " of electric supply is one kilowatt for one hour or one kilowatt-hour, and is the unit on which electric supply is charged.

The following are examples of the unit consumption of some appliances:—

(*a*) A 100-watt lamp will consume 1 unit in 10 hours. (*b*) A 1-kilowatt or 1000-watt fire will consume 1 unit in 1 hour. (*c*) A 27 cu. ft. electrically operated sterilising chest rated at 6 kilowatts will consume 6 units per hour. (*d*) A 3 h.p. electric motor driving a small automatic hammer mill will consume $\frac{3 \times 746}{1000}$ kilowatts = $2\frac{1}{4}$ units nearly per hour, and if 1 ton of grain is ground in 10 hours, the unit consumption per ton of grain ground will be $22\frac{1}{2}$.

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